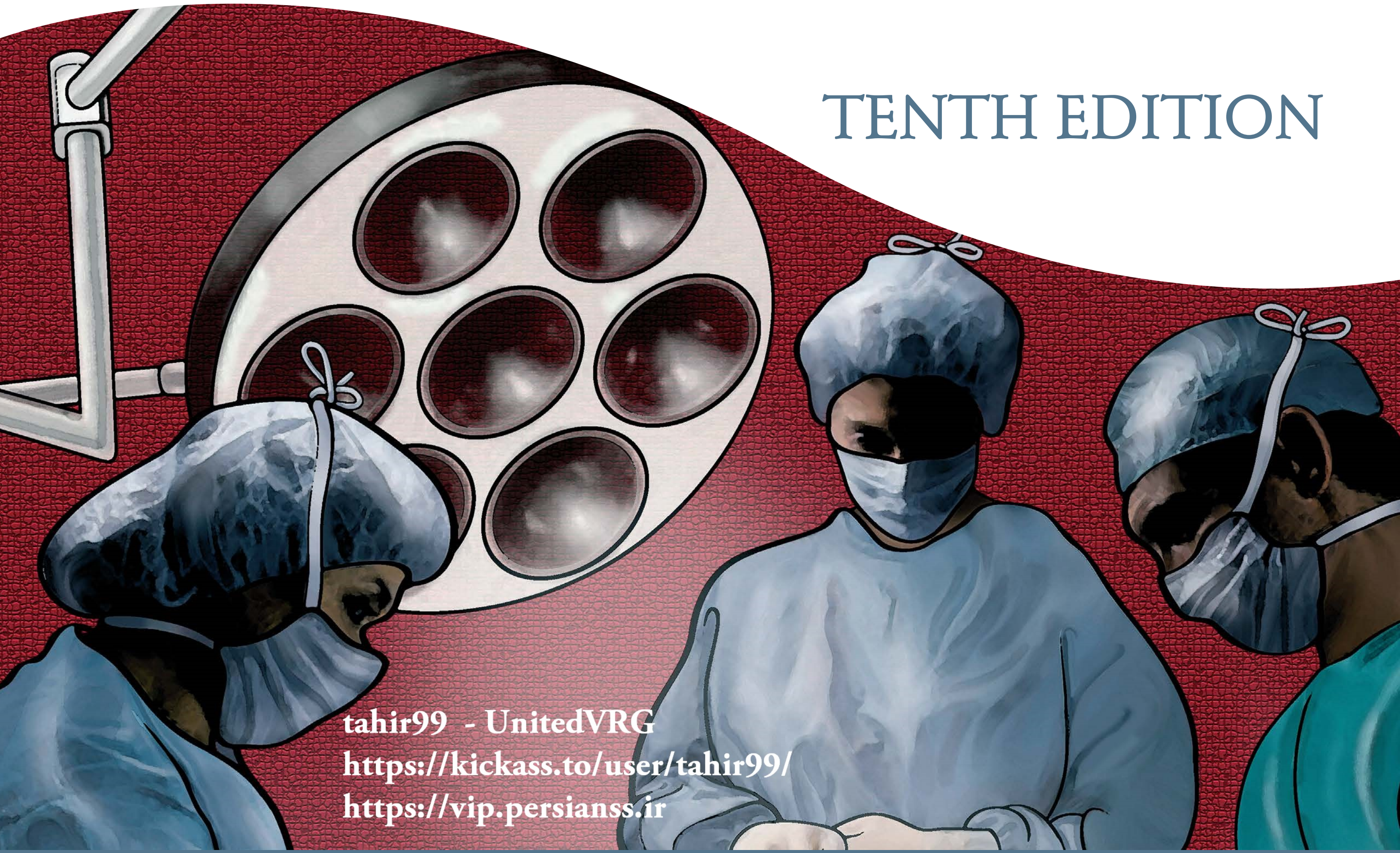
FARQUHARSON'S
TEXTBOOK OF OPERATIVE GENERAL SURGERY



TENTH EDITION

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Margaret Farquharson, James Hollingshead
and Brendan Moran

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TENTH EDITION

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Preface to the First Edition (1954)

Most recently published works on operative surgery are the product of multiple authorship – the work of a number of eminent authorities, each writing on the specialty he has made his own. In support of such composite works, it is often stated that the progress of operative surgery in its many and varied branches has made the subject too vast to be covered adequately by a single author. It is with considerable diffidence, therefore, that I have approached such a task, but I have felt that there was scope for a one-volume book written by a general surgeon, and designed to present, as far as possible, the whole subject of operative surgery in balanced perspective from the viewpoint of the general surgeon.

With these aims in view, I have endeavoured to describe, in detail and with adequate illustrations, all the operations which the junior is likely to undertake himself, and also the more commonly performed operations in which he may have to assist. In the specialised fields of surgery I have described in the same manner such operations as the general surgeon may at times be required to undertake when more expert help is not available.

In most sections an attempt has been made to include a short review of the surgical anatomy of the part; indications for the operation, the choice of procedure, and the pre- and post-operative treatment have been discussed where pertinent. Operations which are less frequently performed, and also those which lie more strictly within the specialised fields, are described more briefly. In this way it has been found possible to contain the work within a single volume of reasonable size.

In the specialised fields of surgery I have sought the advice of several colleagues, and their help, which is acknowledged later, has been invaluable to me. Many of the views, however, that I have expressed on matters pertaining to their specialties, together with the responsibilities for such, are entirely my own.

Eric L. Farquharson

tahir99

Eric L. Farquharson 1905–1970
This photograph was taken
around the time of the publication
of the First Edition

Preface to the Tenth Edition

Eric Farquharson was a young consultant at Edinburgh Royal Infirmary when *Operative Surgery* was first published in 1954, but it was as a General Surgical trainee in the 1930s that he started the project. Surgical training was then very different from that of today and he perceived the need for a textbook that could guide a trainee surgeon through an unfamiliar operation. He did not set out to write a technical step by step manual but rather a book which, in addition to describing the anatomy and operative details, would explain the aims of an operation and give guidance where there was a choice of surgical options. The difficulties that might be encountered were explored and the basis on which intraoperative decisions had to be made was discussed.

During the 1960s and 70s the book became a standard text for the old Surgical Fellowship examinations when a candidate was expected to describe a wide range of operations. Eric Farquharson's vision, though, was less of an examination text, confined to a library, but more of a book that would be readily available in the operating theatre and of value to the practising surgeon.

Surgical training has changed and General Surgery has fragmented in many countries into a number of subspecialties, though there is still a need for a broad range of knowledge and skills for all who participate in the emergency surgical on-call rota. Therefore, as editors we have strived to remain faithful to the original philosophy. The additional editor since the last edition is a grandson of Eric Farquharson. He is at the same stage of his surgical career as his grandfather was when he planned the First Edition and has been in the ideal position to contribute from the perspective of the trainee. The book has been extensively updated with the involvement of many surgical specialists. All the common operations in the General Surgical subspecialties that are likely to be encountered during Higher Surgical Training are described and, additionally, basic techniques are explained for the junior trainee. Although surgeons in training no longer anticipate that they will be expected to undertake unfamiliar operations without supervision, unforeseen circumstances can still arise. With increasing specialisation, even experienced surgeons can sometimes be involved in a surgical emergency, or an intraoperative complication, requiring an operative procedure in a subspecialty other than their own.

A short list of references is given at the end of each chapter. These are a personal selection, including some interesting historical papers, but no attempt has been made to provide a comprehensive bibliography.

In many parts of the world General Surgery has remained a more all-encompassing surgical discipline and in remote hospitals General Surgeons may be the only surgical specialists. When transfer and referral options are unavailable, these surgeons may have to offer a limited service in orthopaedics, neurosurgery, urology and obstetrics. For this reason some operations in other surgical disciplines are included, and here the emphasis is more on what might be achievable in difficult circumstances rather than a more sophisticated procedure if this would be impractical outside a specialist centre.

When many specialists are involved, balance and consistency of style become increasingly challenging. Eric Farquharson was very aware of this difficulty and advocated single authorship as the only practical solution. This is no longer possible and most chapters are now a collaborative effort between the editors and one or more other contributors. However, consistency and cross-referencing between chapters have remained of paramount importance during the editorship.

We hope that this classic textbook will remain of value to General Surgeons, whether already well established in surgery or just embarking on a surgical career.

Margaret Farquharson
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Acknowledgements

All chapters have been extensively updated for this edition and some chapters have passed through as many as six different specialists. We thank all the contributors for the time and effort that they have given to this project. For some there has been a major involvement in one or two chapters, whereas other contributors have been involved in parts of almost every chapter in the book. These teams are listed below:

Breast and endocrine	Rob Carpenter
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	Ian Hunt
Gynaecology and obstetrics	David Farquharson
	Malcolm Farquharson
Hepatobiliary	Rowan Parks (pancreaticobiliary)
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	Fenella Welsh (biliary)
Head and neck	Paul Spraggs
	Simon Keightley (ophthalmology)
	Cyrus Kerawala (maxillofacial)
	Jonathan Blanshard
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Orthopaedics	Jonathan Hobby
Perioperative care	Alison Milne (haematology)
	Piers Wilson (anaesthetics)
Plastic surgery	Ken Stewart
	Chris Wood
Paediatric surgery	Jimmy Lam
Upper gastrointestinal surgery	Ollie McAnena
	Niamh Hogan
Urology	Alan McNeill
	Jimmy Lam
Vascular surgery	Wesley Stuart
	Keith Hussey
	Chris Ray

This is now the tenth edition of *Operative Surgery* and all those who contributed to previous editions will still find some of their writing or illustrations within it. There even remain some passages written by Eric Farquharson himself and some of his original photographs. Much more remains of the work of Forbes Rintoul, who carried this book through another four editions after Eric Farquharson's death. We would like to acknowledge this legacy from everyone involved in the earlier editions.

However, there are also many others to thank, whether they have helped to find a new contributor, lent a photograph or advised over the boundaries of General Surgery in other countries. In the 1954 edition Eric Farquharson acknowledged all who had taught him surgery, the colleagues who had encouraged him to write the book, the publishers and the artists. We would like to thank the team at Taylor & Francis who took over the publication of this edition during its preparation and Gillian Lee for the major task of converting to colour illustrations. Eric Farquharson's final acknowledgement was for the help of his wife, Elizabeth Farquharson. She is now in her late nineties, but retains an active interest in the book and has again read the entire tenth edition before it was submitted for publication.

There are many to whom we owe a debt of gratitude for this book and our sincere thanks are offered to everyone who has made this edition possible.

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1

SKILLS AND TOOLS: KNOTS TO ROBOTS

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SURGICAL SKILLS

Technical skills are important to a surgeon. Their acquisition may be best approached by learning first the traditional core skills encompassed in the Basic Surgical Skills Courses run by the UK surgical colleges. The role of surgical simulators at these and other more advanced courses is steadily increasing.

Although good technique is important, it must be remembered that good surgical practice also includes all the non-operative management: investigation of pathology that might require surgical intervention, and decisions as to what surgery should be advised and whether surgery is appropriate at all. It also includes the preoperative and postoperative care of the surgical patient, with particular attention to patient safety. Even operative surgery is more than just a technical challenge. It is important to remember that perhaps the most crucial operative skill to develop is the ability to make sound intraoperative decisions.[1,2] Not every operation proceeds according to plan and often alternative strategies have to be devised during the procedure itself.

BASIC TECHNICAL SKILLS

Knots, ligatures and sutures

KNOTS

The first skill a trainee surgeon must master is the ability to tie secure knots. The simple and reliable reef knot is well known, and is universally advocated for surgical purposes (Figure 1.1). A *triple* knot is the modification of the reef knot commonly used, and at least three throws are required for security. With slippery monofilament material, multiple throws are required to provide a safe knot, and the ends should not be cut too short. Extra turns in all, or just the first throw, can give added security, especially to a knot of thicker monofilament material.

Knots may be tied using the needle holder to grasp the end of the suture material, which must be wound around the

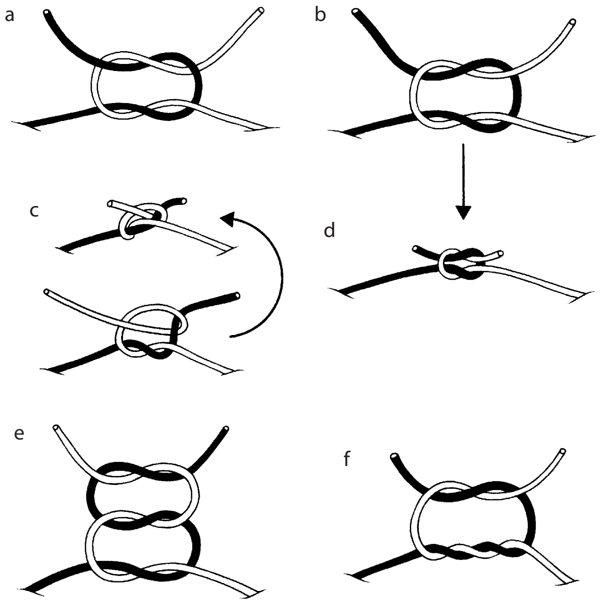

Figure 1.1 *Different types of knot. (a) A granny knot: this is an unsafe knot and should never be used. (b) A reef knot: this must be kept 'square' by tightening in the correct directions and with equal tension on the ends. (c) A reef knot that has been spoiled by careless tightening so that an insecure knot results. The white strand has been pulled to the left. (d) The white strand has been correctly pulled to the right, the black to the left; see (b). (e) A triple knot. (f) A surgeon's knot with an extra turn on the first loop.*

instrument in the opposite direction on the second throw to achieve a reef knot (Figure 1.2). This method is suitable for tying the knots of skin sutures, and is also used for the knots in laparoscopic surgery, which have to be executed entirely by instrument. In open surgery, a hand technique is often preferred for tying the knot of a ligature or of a deep suture, as it is felt to be more secure. The left-hand technique is shown (Figure 1.3). It is important to remember that whichever method is used, if a reef knot is not kept 'square', an insecure 'slip-knot' results. In a deep wound the index finger of the left hand is used after each throw to settle the new throw onto the previous throw and to tighten the knot.

At the end of a continuous suture (for example, closure of the abdominal wall), the surgeon is left to tie a 'loop' to an 'end', which is not ideal, especially in slippery monofilament material. The Aberdeen knot (Figure 1.4) is useful in this situation.

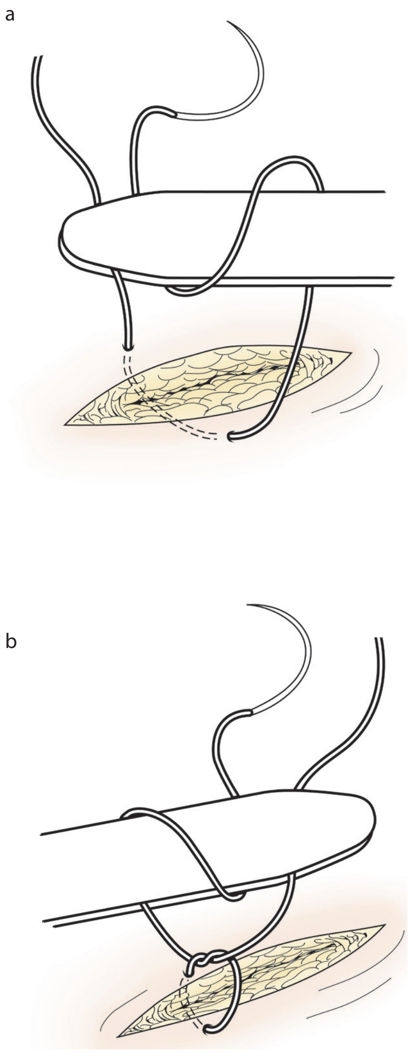

Figure 1.2 *An instrument tie. Note that the suture material is wound in the opposite direction in the second throw to achieve a reef knot. The direction of pull on the suture ends must also be reversed for each throw in order to keep the knot square.*

LIGATURES

The time-honoured method of closing a divided blood vessel is with a ligature. A small vessel may have been cut during dissection and the bleeding point picked up with an artery forceps. Other vessels may have been secured before division between artery forceps. The vessel should be held without a mass of surrounding tissue, which can make secure ligation more difficult. For the 'tying off' or ligation of vessels close cooperation between surgeon and assistant is required. The surgeon passes the ligature material around the forceps, while the assistant holds the forceps, depressing the handle and elevating the point as much as possible, so that the tissue that is clamped is encircled by the ligature (Figure 1.5). Just as the surgeon is tightening the first hitch of the knot, the assistant slowly releases the forceps. Sudden release of the forceps should be avoided, as the blood vessel is liable to slip out of the grasp of the ligature. Every time a vessel is ligated, two 'foreign bodies' are introduced – the ligature itself and the strangulated tissue beyond it. It is therefore important to include as little adjacent tissue as possible in the clamp, to use the finest material consistent with security and not to leave the cut ends longer than necessary.

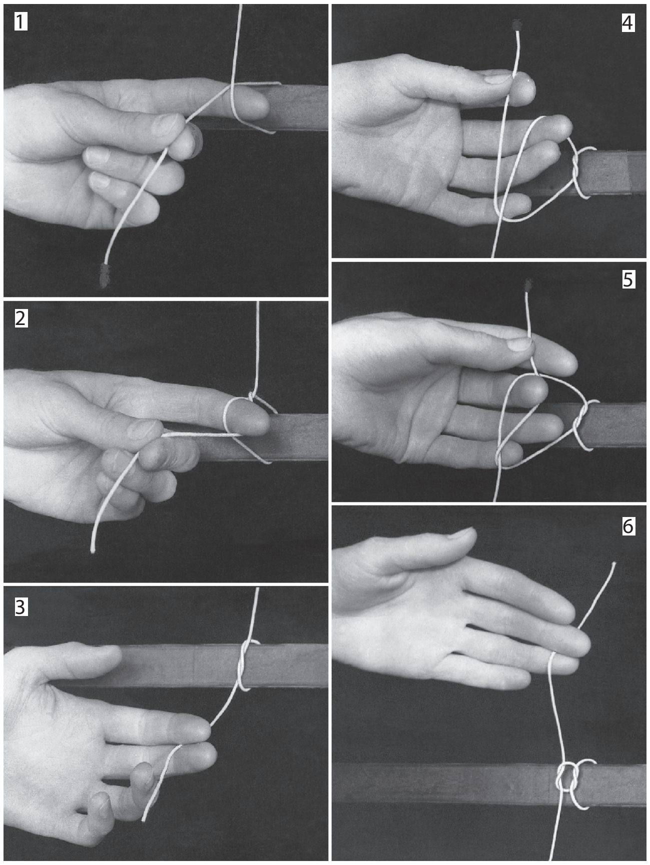

Figure 1.3 *Method of tying a reef knot with the left hand. Note how the knot is kept 'square' by tightening in the correct directions (the end of suture material passing off the edge of each photograph is held in the right hand). This is an original illustration from the 1954 edition. The photographs were taken by Eric Farquharson himself of knot tying by his wife.*

If an artery forceps has been applied to a bleeding point in such a way that it is difficult for the assistant to elevate the point, simple ligation is unlikely to be secure. A short, wide vessel stump poses similar concerns over security. Transfixion ligation is then safer (Figure 1.6). The surgeon passes the suture needle under the forceps through the middle portion of the grasped tissue. The first throw of a knot is then formed and this loop is settled deep to the points of the artery forceps to encircle half of the tissue. The ligature is then passed round, under the handle of the forceps, to encircle the other half of the tissue and again the first throw of a knot is formed. As the surgeon tightens this first throw, and therefore the whole figure-of-eight ligature, the assistant slowly releases

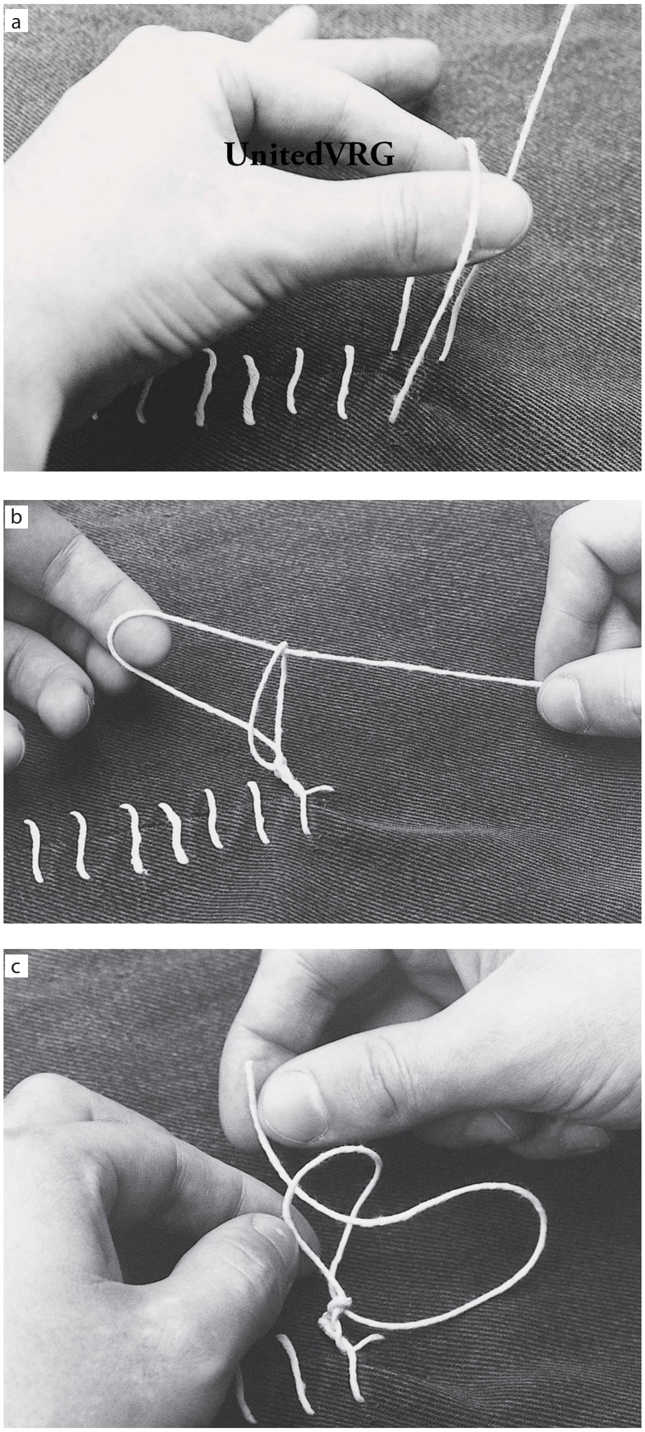

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Figure 1.4 *The Aberdeen knot. (a) After the last suture has been inserted, it is drawn through until there is only a small loop. The surgeon passes an index finger and thumb through the loop to grasp the suture and pull it through to form the next loop. (b) As each new loop is formed, the previous loop is allowed to close to form the next layer of the knot. (c) Finally, the end of the suture – rather than a loop of it – is passed through the loop and the knot tightened.*

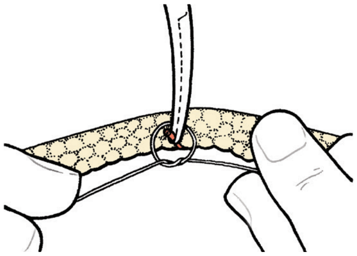

Figure 1.5 *Method of 'tying-off' a bleeding point.*

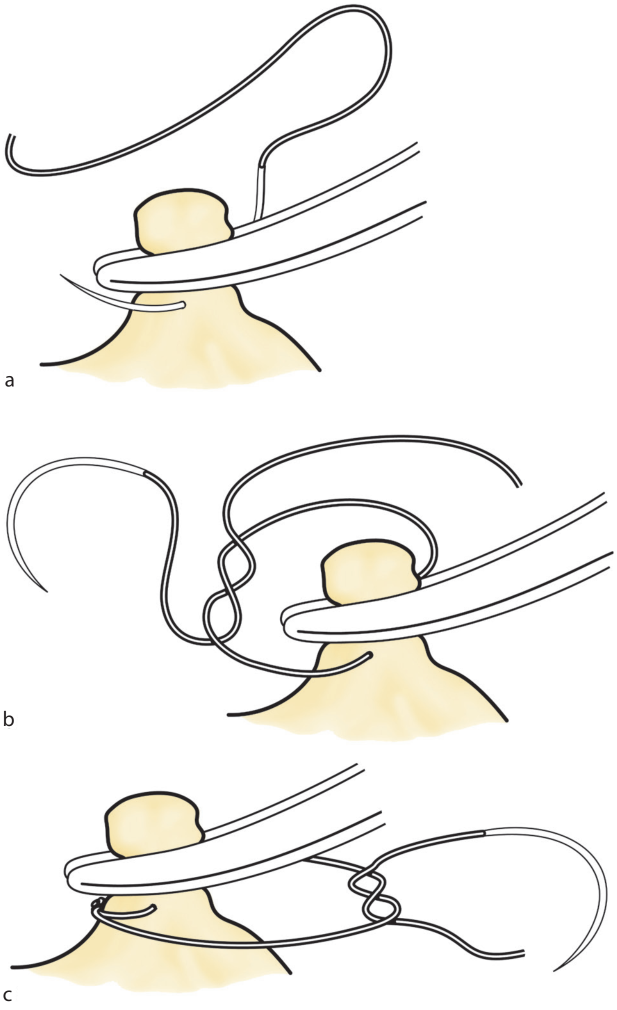

Figure 1.6 *A transfixion suture. The figure-of-eight ligature is prevented from slipping off by its anchorage through the tissue.*

the artery forceps. An even safer transfixion suture favoured by some surgeons is shown in Figure 1.7. In this, the needle is passed a second time through the tissue held in the artery forceps, with the loop of suture material passing under the tips of the forceps. The figure-of-eight is then completed by the knot tied under the handles. These transfixion sutures have greater application in securing major vessels. Occasionally, transfixion ligation of a short stump is unsuitable if it will narrow the underlying more major vessel. A sutured closure is then more appropriate (see Figure 7.27, p. 131).

Sometimes, a thin-walled, wide and therefore easily torn vein can be dealt with more safely by passing a ligature above and below the point of intended division and only dividing the vessel after both ligatures are tied (Figure 1.8). An artery forceps is first passed carefully under the vessel and the jaws opened sufficiently to grasp the ligature material, which is carried to the open jaws by a second artery forceps – 'a *mounted* tie' (Figure 1.8a). The ligature is then drawn round under the vessel.

Coagulation diathermy is an alternative to ligation for sealing small blood vessels (see Appendix II). A vessel may be coagulated before division or after it has been clamped and divided. It can also be coagulated when it has been identified as a bleeding point in the dissection plane. When using bipolar diathermy the vessel is held in the diathermy forceps and the current passes from one point of the forceps to the other, coagulating and sealing the vessel held between them. When using monopolar diathermy a vessel can either be picked up in the diathermy forceps and coagulated, or it can be secured first with artery forceps and the diathermy current passed down the artery forceps from the diathermy wand. Extra tissue held in forceps leads to less effective coagulation and greater tissue damage. In situations where no diathermy is available, most vessels clamped in an artery forceps should be ligated. However, the pressure of the artery forceps left on for a minute or two and then released may be sufficient for a small vessel, but there is a danger of bleeding restarting later.

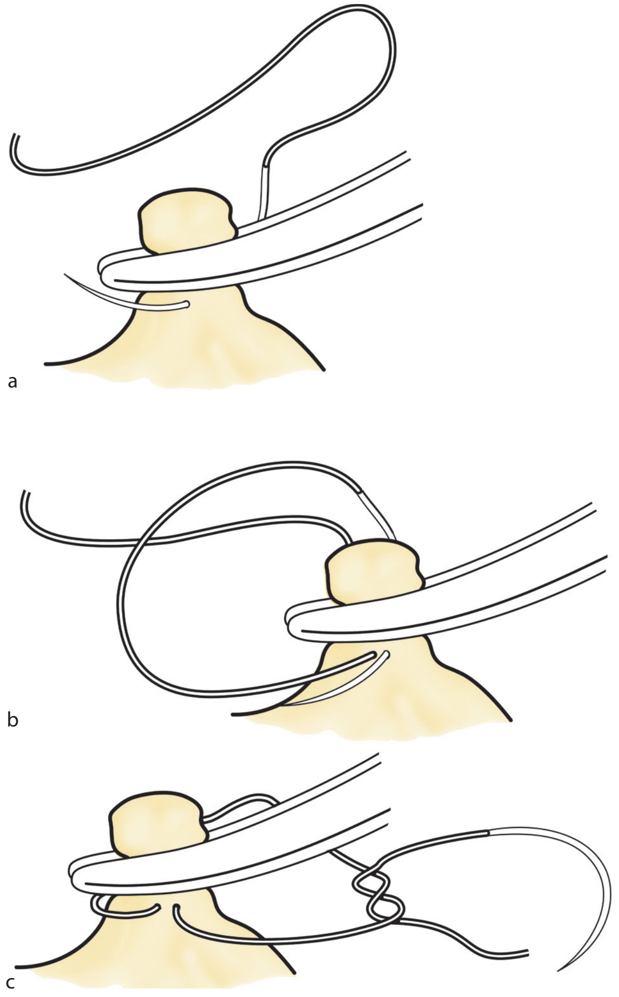

Figure 1.7 *An alternative transfixion suture, which passes twice through the tissue.*

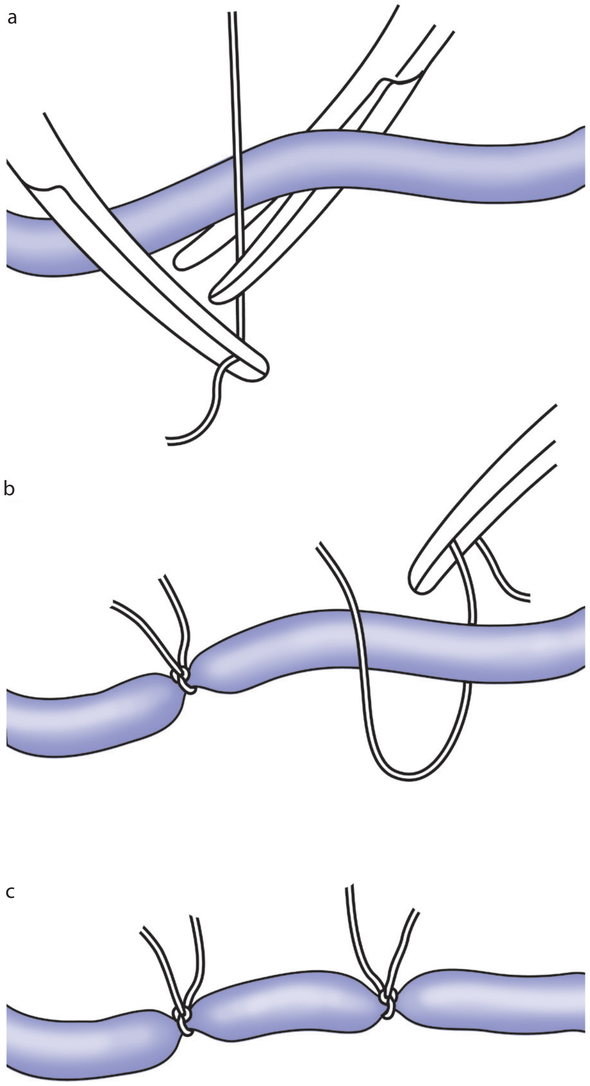

Figure 1.8 *(a) A 'mounted tie' is used to carry a ligature to the open jaws of an artery forceps passed beneath a vessel. (b) After ligation the procedure is repeated. (c) An isolated section for division is obtained.*

SUTURES

Closure of a skin wound is often the first surgical procedure a trainee undertakes and the choice of suture method for skin surgery is covered in more detail in Chapter 2. Sutures, however, are also used for gastrointestinal, urological and vascular anastomoses, for abdominal wall closure and for the repair of tendons and nerves. In general, sutures are designed to hold healthy tissue in apposition to allow healing and their support is required until the tensile strength in the wound or anastomosis is adequate to prevent disruption. Too tight a suture should be avoided as it merely cuts through the tissue or causes ischaemia. When judging tension it should be remembered that all sutures become tighter at 24–48 hours as traumatised tissue swells. An additional difficulty is the tendency for the whole suture to tighten as the knot is tightened.

Suture material, whether monofilament or braided, may be bioabsorbable or remain in the tissue unless removed. Monofilament material is less traumatic to tissue but a braided suture is easier to handle, with more secure knots. Non-absorbable sutures are needed for vascular anastomoses but are unsuitable in the biliary or urinary tract, where they have been shown to cause stone formation. Chronic abscesses can also form around non-absorbable sutures, particularly if braided. Bioabsorbable sutures lose strength at different rates and are all associated with a tissue reaction as this occurs.

Therefore, the choice of suture material is sometimes crucial, although more often it is mainly a matter of surgeon preference, cost or availability. Sutures made from different materials may have similar properties. Conversely, sutures of similar materials may exhibit different behaviour, reflecting the manner in which they have been manufactured. This has resulted in the increased use of trade names. The properties of some sutures, in particular those to which later references are made, are identified in Table 1.1.

Dissection

After incision of the skin, almost every operation relies on dissection. This may be to excise a lipoma in the subcutaneous fat or to find the least traumatic access to a long bone by dissecting between muscle bellies. It may be to mobilise a segment of colon with its lymphatic drainage intact or to lift intra-abdominal viscera to expose a kidney. In all dissections, natural planes between structures can be found and developed by a blunt or a sharp method of dissection.

In *blunt dissection*, reliance is placed on the assumption that natural cleavage occurs between structures. If, however, there is scarring from previous surgery or inflammation, the line of least resistance to separation may instead be through adjacent structures such as major vessels or loops of bowel. Blunt dissection should be used sparingly and with caution. Forceps or scissors, inserted into the plane of dissection, are gently opened or the surgeon's fingers can feel the plane and separate the structures. A pledgelet swab held in forceps and used to push fat away from an underlying vessel or duct is another form of blunt dissection.

In s*harp dissection* the surgeon is following a plane under direct vision. Identification of the plane may be by a change in colour or size of fat lobules at the edge of an organ or on the surface of a cyst or a lipoma. It may also be in an areolar plane, which opens when the tissue is held on stretch. These areolar planes are between adjacent structures of different embryological origin. Only fine bands of tissue, which are almost avascular, cross these planes. They are divided under direct vision with scalpel, scissors or diathermy. It is always important to divide the most stretched band, which then allows distraction to show the next band to be released. Dissection, therefore, should not be continued exclusively in one area but must move along the plane. Increase in bleeding is nearly always a sign that the surgeon has wandered out of the correct plane or that the underlying pathology, whether inflammatory or malignant, has itself breached the plane.

Table 1.1 *Suture materials.*

Non-absorbable	Braided	Silk
		Ethibond™ (polyester)
	Monofilament	Nylon
		Prolene™, Surgipro™ (polyester)
		Stainless steel wire
Strength lost within 2 weeks	Braided	Vicryl Rapide™, Dexon™ (polyglycolic acid)
	Monofilament	Plain catgut
		Caprosyn™, Monocryl®
Strength lost between 2 and 4 weeks	Braided	Vicryl™, Polysorb™ (polyglycolic acid)
	Monofilament	Chromic catgut
Strength lost between 4 and 6 weeks	Monofilament	PDS™ (polydioxanone sodium), Maxon™

Reduction of bleeding

Blood obscures the view for the surgeon and all surgery is easier if bleeding can be reduced. In addition, blood loss increases morbidity. Tourniquets or vascular clamps can give the surgeon an almost bloodless operative field in some circumstances, and even temporary finger pressure on an artery proximal to an injury can be a useful manoeuvre in an emergency. Bleeding from small vessels can be reduced by infiltration of adrenaline containing local anaesthetic or saline solution. Venous ooze can be particularily troublesome if there is venous engorgement and simple positioning of the patient can reduce this significantly. The head-down tilt (Trendelenberg) position for varicose vein and pelvic surgery and the head-up tilt for thyroid surgery are examples. However, the rare, but potentially lethal, complication of air embolus must be remembered. More sophisticated methods for reducing central venous pressure for liver surgery are discussed in Chapter 21. The haemodynamic conditions should be returned to normal, if possible, before completion of the operation to reveal previously unidentified bleeding points.

TOURNIQUETS

Tourniquets should be used for most fine procedures on the distal limbs. A finger or toe tourniquet made from the finger of a rubber glove can also exsanguinate the digit as it is rolled down into position (Figure 1.9a). It is useful for minor surgery on the distal portion of a digit, but for any more major procedure a pneumatic tourniquet (Figure 1.9b) is preferable. The tourniquet is applied and, before inflation, the limb is emptied by elevation alone or by elevation combined with firm application of a rubber bandage from the digits up to the tourniquet. The tourniquet is then inflated to 50 mmHg above systolic pressure and the bandage removed. The pressure is maintained at this level until surgery is completed. In a fit young patient the tourniquet may be left inflated for up to 90 minutes. Alcohol-based antiseptic skin preparations should be avoided as seepage of the solution under the tourniquet may result in iatrogenic chemical burns.

SOFT VASCULAR CLAMPS

An isolated artery or vein can be temporarily occluded with a soft clamp. This technique is extensively used in vascular surgery and is described in more detail in Chapters 6 and 7. Clamps have advantages over tourniquets as distal ischaemia is usually avoided by collaterals. When there are no collaterals or they are inadequate, temporary shunts may be used during a vascular procedure. It must be remembered that the soft clamp used to occlude the vascular inflow to the liver or kidney to reduce parenchymal bleeding is inevitably an ischaemic manoeuvre similar to a limb tourniquet.

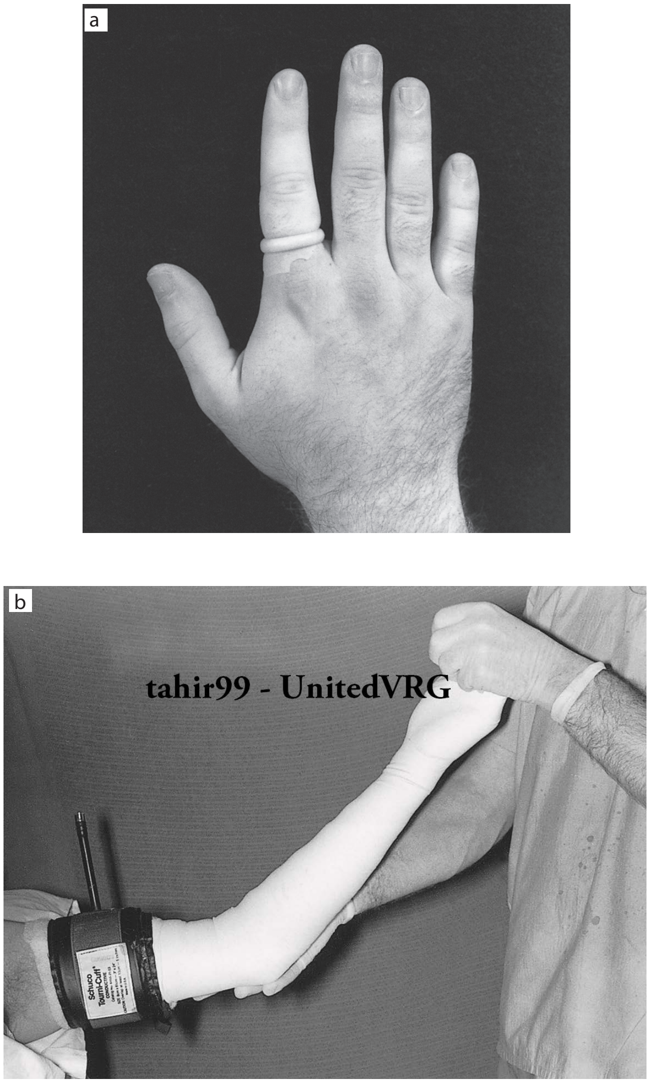

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Figure 1.9 *(a) A finger tourniquet, fashioned from a surgical glove finger with the tip cut off, is placed on the finger and rolled to the base. A size should be chosen that is a firm fit before it is rolled. (b) A pneumatic tourniquet. After applying the tourniquet around the upper arm, the arm is exsanguinated by elevating it and wrapping a rubber bandage around it, starting distally. The tourniquet is then inflated and the bandage removed.*

MORE SOPHISTICATED SURGICAL TOOLS

The techniques discussed below are in standard use in operating theatres in the United Kingdom. In many instances the advantages over the basic method are marginal and related mainly to speed, but in other instances they make a difficult manoeuvre easier and safer. The disadvantage is one of cost and many surgeons who are working in countries with major health care budget restrictions will find these alternatives unaffordable.

Ligature and suture alternatives

There is increasing use of clips and staples for securing vessels, and these devices have proved invaluable both in minimal-access surgery and in situations where access is difficult. Small linear cutting stapling devices have been of particular benefit in the safe division of large veins, where the length of the vein is too short to accommodate ligatures. The right renal vein and the hepatic veins are examples. It is a faster and more secure technique than that of oversewing the vein. The angled head of these stapling devices allows access into restricted surgical fields. Other developments have been in vessel sealing technologies.[3] LigaSure™ and Ultracision® are electrothermal bipolar tissue sealing devices; Harmonic® coagulating shears use high-frequency mechanical vibrations in the ultrasonic range to fragment tissues and seal small vessels. These have proved useful devices for dividing the mesentery of the bowel in both open and laparoscopic surgery.

Simple skin clips have long been an alternative to sutures for apposing skin, but more sophisticated devices were required before there was an alternative to sutures for anastomosing bowel or suturing a vein. The linear and circular stapling devices used in abdominal surgery are described in more detail in Chapter 14 (p. 237). Whereas the contribution of the linear staplers has been mainly that of speed, the circular staplers have greatly simplified some oesophageal and low rectal anastomoses where access makes a sutured anastomosis very difficult.

More sophisticated dissection techniques

ELECTROSURGICAL DISSECTION

Initially, diathermy was used almost exclusively to coagulate tissue and was thus a faster way to deal with small blood vessels. Increasing technical sophistication has allowed a range of diathermy settings to include various blends of coagulation and cutting modes. Sharp dissection is now increasingly performed with monopolar diathermy. It has the advantage that it prevents multiple small bleeding points in areolar planes and can give the surgeon an almost bloodless field as dissection proceeds; larger vessels still require individual attention. It is important that dissection is combined with retraction to open the plane and keep any fine structure to be divided on stretch. Diathermy of tissue that is not on tension produces charring. Skin incisions can be made with diathermy and it almost eliminates the small bleeding points in the dermis. Similarily, if bowel is divided with diathermy, submucosal bleeding is significantly reduced. Diathermy dissection is, however, not without risk. The general risks of diathermy are discussed in Appendix II but there are also local risks. The surgeon is more likely to stray from the correct plane of dissection and often more damage is caused before the mistake is realised. There is also concern over thermal damage to adjacent nerves such as the autonomic plexi during pelvic dissection and the recurrent laryngeal and facial nerve in neck surgery.

ULTRASONIC DISSECTION

An *ultrasonic scalpel* can also be used as an alternative to a diathermy hook in laparoscopic dissection. Although the ultrasonic Harmonic^{R} scalpel generates heat, the zone of thermal energy produced is less than with monopolar or even bipolar electrocautery. Additionally, less smoke and steam are generated, both of which can impair visibility during a laparoscopic procedure.

The *Cavitron ultrasonic surgical aspirator* (CUSA) has generally replaced finger fraction for dissection through the liver. It disrupts liver parenchyma, exposing small vessels which are then secured. More detail is given in Chapter 21.

LASER TISSUE DESTRUCTION

A laser beam can pass harmlessly through superficial tissue to destroy the deeper tissue on which it has been focused. Lasers are not used extensively in general surgery but have an increasing role in ophthalmology and prostatic surgery.

MINIMAL-ACCESS AND VIDEO-ASSISTED SURGERY

The minimal-access techniques for gastrointestinal and vascular procedures are of particular interest to the general surgeon, but there has been a parallel development in other surgical disciplines. This area of surgery has expanded enormously in the last 20 years in those countries that can afford the expensive equipment and its skilled maintenance. Surgeons are no longer the only interventionalists and cooperation in a multidisciplinary setting has become more important. A surgeon may refer a patient to another discipline for a minimal-access procedure or a patient may be referred to a surgeon after a minimal-access intervention in another discipline has failed or caused complications.

When two options are considered – a traditional open operation or a minimal-access procedure – it is not only important whether an operation can be done by a less invasive technique, but whether it is better or worse done in this way. This decision is related to patient and disease factors, but the relative skill of the operator in each method is also of great importance.

Patients are usually delighted that they can be saved a 'major operation'. A short hospital stay is anticipated and a faster recovery with either no external wound or only small port site wounds. Unfortunately, this leads many to believe that the procedure itself, and the inherent risks, are minor compared with traditional open surgery. In many cases, although the access is minimal, the surgery itself is still major. Preoperative discussions are important here or the scene is set for blame and even litigation if complications arise.

Interventional radiology

Interventional radiology has an increasing role in the management of the surgical patient. In every scenario a minimal-access technique under image control has the potential to replace a major surgical intervention. One example is the use of cross-sectional imaging, such as CT, ultrasound or MRI, to demonstrate the presence and position of pus. Adjacent vital structures are also delineated and a drain can safely be inserted under image control. Nephrostomy drainage of an obstructed kidney is now routinely established using a similar technique. Lumbar sympathectomy is now a radiological rather than a surgical procedure. The sympathetic chain is ablated by a chemical paravertebral injection under image control.

Angiography as a diagnostic tool developed into various therapeutic interventions. Fibrinolysis and angioplasties, with or without stents, have saved many patients from major vascular operations and even endovascular aneurysm repair is increasingly an option (see Chapters 6 and 7). Selective arterial embolisation is another radiological intervention with great potential for the surgeon. Preoperative embolisation can be used to reduce the vascularity of a renal tumour. More often it is used as an alternative to surgery to obliterate feeding arteries and arrest haemorrhage. In the gastrointestinal tract it has proved particularily valuable in angiodysplastic colonic bleeding and in secondary haemorrhage after radical gastrectomy. Embolisation may also have a major role in the control of haemorrhage from a fractured pelvis or a traumatised liver. Venography allows the insertion of venous stents, inferior vena caval filters for the prevention of pulmonary emboli and testicular vein embolisation to treat varicoeles. Endovascular transhepatic insertion of a portosystemic shunt (TIPSS) has virtually replaced any open portostystemic shunt for portal hypertension. All these options are discussed in the relevant chapters. Cardiac angiography, including angioplasty and stents, is traditionally undertaken by cardiologists rather than radiologists. Ablation of abnormal electric foci in the myocardium, closure of septal defects and even some valve surgery can be undertaken by this route.

Oesophageal, pyloric and colonic obstructions were once managed exclusively by surgeons. In all of these an endoluminal stent can be placed across the obstruction, under image control by the radiologist, although for some stents additional endoscopy is needed. These stents have reduced the need for palliative surgery in a patient with advanced malignancy.

Interventional gastroenterology

Interventional gastroenterology has also expanded in recent years. Originally, the endoscopist looked directly down the endoscope but now the camera on the endoscope allows the procedure to be visualised by watching the video image on a screen. Oesophageal varices are routinely treated endoscopically by sclerosant or banding techniques and bleeding duodenal ulcers by adrenaline or sclerosant injection or by laser photocoagulation. Endoscopic retrograde cholangiopancreatography (ERCP) is usually combined with a therapeutic manoeuvre, such as the placement of a stent in biliary obstruction, or with sphincterotomy and extraction of stones from the biliary tree. Endoscopy can be employed for the drainage of a pancreatic pseudocyst. Colonic polyps are routinely removed at colonoscopy. The ability to raise a polyp off the muscle coat by submucosal injection of a dilute solution of adrenaline has expanded the technique so that larger flatter polyps in the thinner walled right colon can also be removed, and a similar manoeuvre is employed for endoscopic submucosal resection of an early gastric cancer (see Chapters 18–23). Many of these procedures, undertaken by gastroenterologists in the endoscopy suite rather than by surgeons in an operating theatre, are often not viewed as operations. However, a sphincterotomy or submucosal excision of a cancer should be viewed as surgery whoever performs it.

TRANSANAL ENDOSCOPIC MICROSURGERY

Whereas most of the developments described above have been dependent on improvements in flexible scopes and of instruments that can be passed through the small operating channels, transanal endoscopic microsurgery (TEMS) is performed through a specially designed rigid proctoscope. It is an option for the excision of large villous adenomas in the rectum. Excellent views and small instruments designed to pass through the working ports allow very precise surgery up to at least 15 cm. The technique, and its place in the surgery of rectal cancer, are discussed in more detail in Chapters 23 and 24.

LAPAROSCOPY, THORACOSCOPY, ARTHROSCOPY AND THE CREATION OF ARTIFICIAL SPACES

The peritoneal, pleural and joint cavities are ideal delineated potential spaces to inflate for video-assisted minimal-access surgery. Artificial spaces can also be created within loose areolar tissue and an increasing number of operations can be undertaken by this minimal-access approach.

Laparoscopic access and some general intra-abdominal principles are discussed in Chapters 13 and 14. In all chapters, minimal-access operations that are in general use are described. However, in all video-assisted surgical procedures there are similar challenges for which specific surgical techniques have been developed.

LAPAROSCOPIC SURGICAL PROCEDURES

In all minimal-access operations similar challenges are encountered. The basic principles of surgery, tasks such as retraction, dissection and haemostasis, and the intended end result are the same as in open surgery. The techniques used to achieve these tasks, however, differ and are described below for laparoscopic surgery. The surgeon's hands are not in the operative field and long-shafted instruments have to be manipulated from outside the body. Changing from one instrument to another is more time-consuming than in open surgery. Some manoeuvres are easier laparoscopically but other very basic open skills, such as suturing, are more challenging. Palpation is no longer an option and the operator has to rely on vision alone. However, views are excellent once the surgeon has adjusted to the two-dimensional video picture and the inevitable distortions of size.

VISUALISATION

Good-quality laparoscopic visualisation is dependent on the laparoscope, the camera and the display stack. Choice of camera and stack is largely limited by cost and available equipment, but laparoscope sizes ranging from 3 to 10 mm are available and the viewing angle varies from 0 to 45 degrees. Smaller laparoscopes and those with a more angled view in general provide less light and inferior views. The advantage of an angulated scope, when manipulated by a skilled assistant, is the ability to look around structures that might otherwise be in the line of sight or to look at the operative field from different directions through the same port.

A poor laparoscopic view may be caused by a number of factors. The gas within the operating cavity will be at high humidity and body temperature. If a cold scope is introduced into the cavity, condensation will form on the lens thus obscuring the view. This can be prevented by warming the scope or using propriety anti-misting solutions. Repeated or prolonged removal of the scope from the patient will allow it to cool down and should be avoided. Diathermy and ultrasonic dissection produce smoke and cellular debris, which obscure the view, and these can be cleared by allowing a constant controlled escape of gas through one of the ports. Meticulous haemostasis is also important, as not only does blood obscure the tissue planes, but blood is poor at reflecting light and significant volumes of blood within the operating cavity result in low light levels and poor views.

DISSECTION

Sharp dissection in laparoscopic surgery may be carried out using scissors, diathermy or ultrasonic dissection. The entire non-insulated part of an instrument used for diathermy must be visible prior to applying diathermy current to prevent injury to structures outside the field of view. It must also be remembered that the ultrasonic dissector retains heat and may cause a thermal injury even after the power has been released.

Blunt dissection under direct vision is used extensively during laparoscopic surgery. The plane of dissection should first be recognised, and is then put under tension by retraction from the assistant and the non-operating hand of the surgeon. Tissue to either side of the plane may then be pulled away from it, using either the same instrument as used for sharp dissection or a laparoscopic pledget.

HAEMOSTASIS

Tying a ligature is much more difficult laparoscopically and other techniques are usually used for haemostasis. Small vessels may be divided and sealed by an ultrasonic dissector or diathermy. For larger vessels, clips or haemostatic stapling devices as described above are usually used.

Where a vessel is divided inadvertently or a clip or stapler fails, prompt control of the resulting haemorrhage is needed to maintain a good view of the operative field, and it is important that any instruments required are available quickly. If a bleeding vessel can be seen and grasped safely, then it can be controlled by any of the above techniques. Otherwise, haemostasis can normally be achieved temporarily by application of direct pressure using a small tonsil swab, which can be inserted through a laparoscopic port, or with a laparoscopic pledget. With bleeding controlled temporarily it may prove possible to gain access to the bleeding vessel safely and complete haemostasis. If it is not possible to control bleeding without risking damage to adjacent structures, it may be necessary to convert to an open operation.

LAPAROSCOPIC KNOTS AND SUTURES

Knots may be tied intracorporally using laparoscopic instruments, or extracorporally by hand. A locking slip knot such as the Meltzer knot (Figure 1.10) can be tied by the surgeon, and the resulting loop introduced through a port with the long end of the ligature remaining on the outside. The loop is passed over the structure to be ligated and then tightened using a knot pusher. Pre-tied loops such as the Endoloop®, with a disposable inbuilt plastic pusher, are available and may be used instead. A long ligature may be passed through

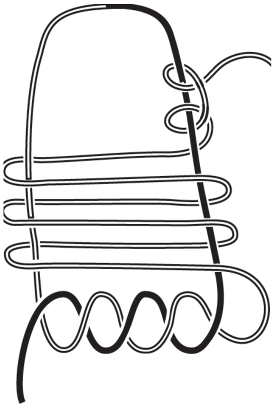

Figure 1.10 *A Meltzer locking slip knot suitable for braided suture material.*

a port, around a structure to be ligated, and back out through the same port. Individual throws of the knot are then tied extracorporally by hand and tightened by use of a long laparoscopic knot pusher.

Intracorporal suturing and knot tying is identical in principle to suturing and knot tying in open surgery, but made more difficult by the two-dimensional view, the limited space available and the difficulty of making throws with two instruments both approaching the operative field from the same direction. Most laparoscopic graspers do not hold a needle securely enough for accurate suturing, and a pair of laparoscopic needle holders should be used instead. A long suture is difficult to tie within the visual field of the laparoscope, and sutures should be cut down to 10–15 cm. As the direction from which the needle holder approaches the operating site is fixed by the position of the port used, accurate positioning of the needle within the needle holder is necessary for an accurately placed stitch. The needle is most easily positioned for placing a stitch with the right hand by first grasping it loosely near the tip with the left hand needle holder. If the needle is incorrectly orientated, it can now be adjusted by grasping the suture thread close to the needle with the right hand needle holder and pushing or pulling as required. Once the needle is correctly orientated it can be picked up ready for suturing.

Various methods of tying the knot exist and just one is described here. After placing the stitch with the right hand, the needle is grasped near its tip by the left hand needle holder and the stitch is pulled through a short distance only. The right hand instrument then grasps the suture as it exits from the tissue and pulls a loop of suture material towards the camera (Figure 1.11a). The combination of this loop and the curve of the needle makes it easy to wrap two turns of the suture around the right hand needle holder by rotating it in an arc (Figure 1.11b) prior to grasping the end of the suture material as for a standard instrument tie (Figure 1.11c). The throw is tightened and then the same procedure repeated in reverse for the second throw. Where a knot needs tying under tension or slips during tying, a useful technique can be to create an intentional slip knot. Firstly, a standard reef knot with two throws is formed. Then one end of the suture is grasped both above and below the knot and pulled taut (Figure 1.12a). The knot will turn into a slip knot with a palpable give, and it can than be tightened down as required (Figure 1.12b). Finally, pulling each end of the suture laterally will convert the knot back into a secure square reef knot (Figures 1.12c and d), again with a palpable give, to which further throws can be added if required.

TECHNIQUES UNDER DEVELOPMENT

The following techniques are showing promise but at present are only employed in a few surgical centres.

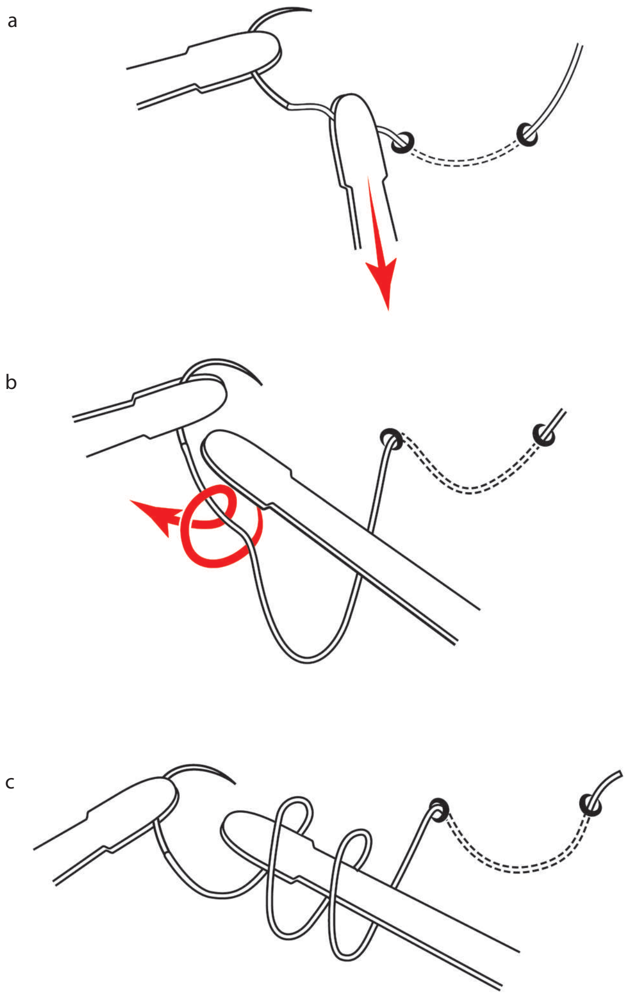

Figure 1.11 *An intracorporeal suture ligation. (a) The suture is only pulled through sufficiently to allow it to be grasped by the second needle holder close to the needle and pulled to form a loop. (b) The second needle holder is then rotated around the loop as shown by the arrow. (c) Two turns around the needle holder have been achieved and the short end can now be grasped to complete the first throw of the knot.*

NEEDLESCOPIC SURGERY

When only 2-mm and 3-mm diameter instruments are used in combination with a 3-mm laparoscope, the technique is described as needlescopic. Several intra-abdominal and intrathoracic operations have proved suitable for this technique but it may have its most important place in paediatric surgery.[4]

SINGLE INCISION LAPAROSCOPIC SURGERY

Laparoscopic surgery may be carried out through a single incision into which is placed one large 15-mm port. This port contains passages for a 5-mm camera, and two 5-mm

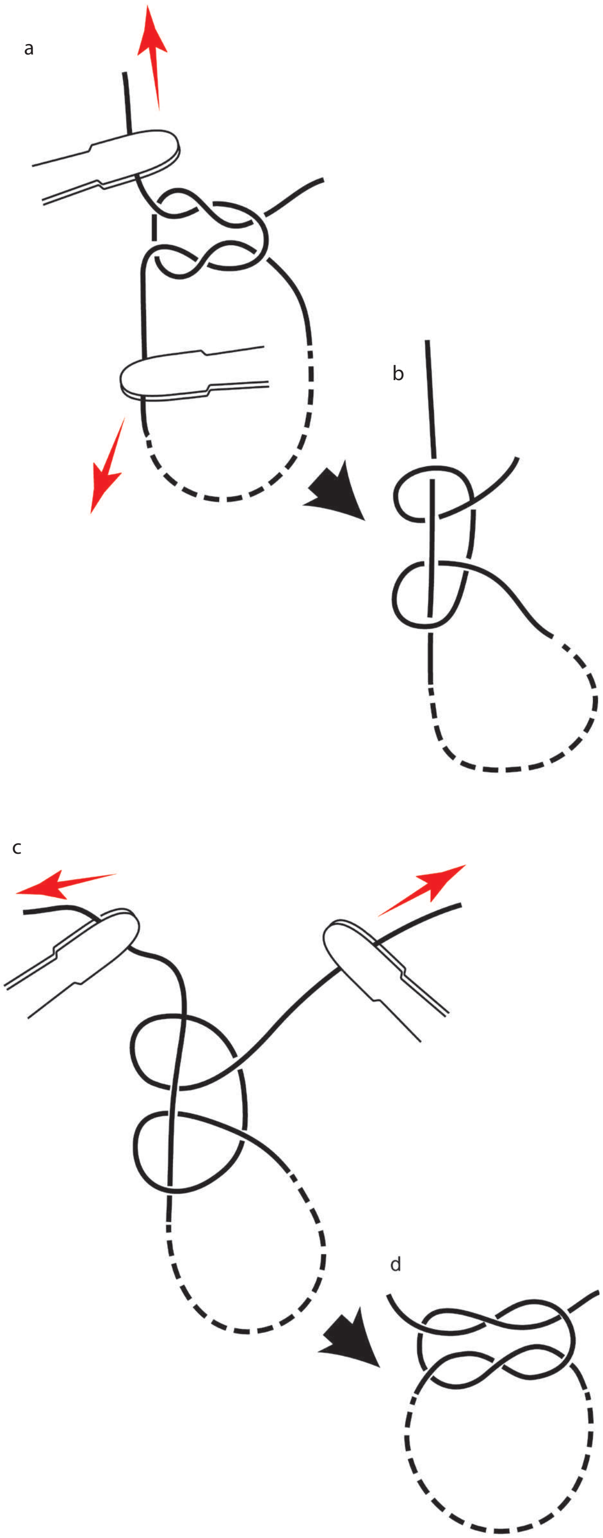

Figure 1.12 *It may be difficult to maintain tension on a knot during a laparoscopic tie. (a) A reef knot has been created but the suture is too loose. Traction in the directions shown will convert it to a slip knot. (b) This slip knot can be tightened. (c) Traction in the directions shown will convert the knot back into a reef knot. (d) A reef knot, which is securing a snug suture.*

instruments. The instruments are angled part way down their shafts so that they can pass obliquely through the port, and then angle back to converge on the operating field from either side. Where the single port is hidden at the umbilicus or placed at the site of a planned stoma, virtually scarless surgery can be carried out.

NATURAL ORIFICE TRANSLUMINAL ENDOSCOPIC SURGERY

Obtaining surgical access through an incision within a natural orifice results in no visible scars, and this approach is well established in procedures such as vaginal hysterectomy and transnasal access for pituitary surgery. More recently, incisions within natural orifices such as the vagina or stomach have been used to gain access to the abdominal cavity for video-assisted intra-abdominal operations such as transvaginal cholecystectomy.[5] The technique is still in the early stages of development and has yet to be taken up widely.

ROBOTIC SURGERY

Robots initially proved promising in urological, orthopaedic and cardiothoracic surgery. Increasingly complex procedures have now been reported in robotic-assisted laparoscopic intra-abdominal surgery.[6,7] However, although they overcome some of the difficulties of access and manoeuvrability of instruments, little clinical benefit has yet been proven. Most operations take longer and the current robot systems are very expensive, limiting their routine use.

INTRAOPERATIVE DECISIONS

Even standard operations are never identical and each minor adaptation involves a decision by the surgeon. These routine decisions over access, degree of mobilisation, viability of tissue or the tension in an anastomosis or wound closure can be likened to the decisions a driver has to make regarding speed or overtaking on any journey; the route may be the same but traffic and weather conditions vary. More major decisions can relate to variations in vascular anatomy, unexpected pathology or complications during surgery. Exploration of an apparently simple infected area may reveal extensive dead tissue or an intended appendicectomy instead uncover other pathology. A vascular reconstruction may have to be modified when a donor or recipient artery proves unsuitable. A malignancy may be more advanced than anticipated and the choice between very radical surgery or palliative surgery is not always straightforward. A gastric conduit may necrose and an alternative reconstruction may have to be considered. When involved in major operations the surgeon must always consider his ‘get-out strategy’ – how to reconstruct a functional gastrointestinal tract if the next phase of the dissection shows tumour resection to be impossible, or how to restore distal perfusion if vessels prove unsuitable for bypass grafts.

The way in which these intraoperative decisions are taken can only really be learnt in the operating theatre. However, throughout this book these issues have been addressed in the relevant sections.

SALVAGE SURGERY

This implies an often temporary solution to a challenging situation, whether caused by trauma, a disease process or a complication of previous surgery. The operation is designed to secure the survival of the patient and definitive surgical reconstruction is delayed. There is an old surgical adage 'It is better to have a live problem than a dead certainty.' Salvage surgery embraces this concept.

CONTROL OF HAEMORRHAGE

Arterial trauma can normally be repaired or reconstructed at the initial exploration. However, a surgeon with limited vascular experience or working in a conflict zone might have to opt for a temporary solution. For example, a torn femoral artery can be ligated in the groin to save a patient's life during transfer to specialist facilities. Limb viability may be maintained on collaterals or by a shunt until a reconstruction can be undertaken in more appropriate circumstances. Packing a bleeding liver (see Chapter 15, p. 250) or ligating the internal iliac vessels for severe pelvic haemorrhage are other salvage manoeuvres (see Chapter 5, p. 71 and Chapter 27, p. 514) Postoperative haemorrhage within a few hours of an operation is relatively straightforward to deal with at exploration – a haematoma is evacuated, a vessel that is actively bleeding is secured and the area drained. Secondary haemorrhage, around 10–14 days postoperatively, is associated with infection. The control of individual vessels in friable tissue is seldom possible and a salvage procedure with packing is more appropriate. Within the abdomen, embolisation of feeding vessels should be considered as an alternative to surgery (see Chapter 15, p. 242). A secondary haemorrhage from a disrupted infected arterial graft anastomosis poses dual salvage challenges: the control of haemorrhage and the restoration of distal perfusion (see Figure 7.10, p. 119).

EXCISION OF NECROTIC TISSUE AND INFECTED PROSTHESES

Pus and infected collections must be drained, whether surgically or radiologically. When pus is associated with an infected prosthesis, drainage and antibiotics is seldom sufficient. Initial resolution is normally followed by further infective episodes until the prosthesis is removed. Although this seldom has to be undertaken in an emergency, the initial surgery is often again a salvage procedure. The first operation is to remove the infected artificial joint or mesh and the second, some months later when all infection has been eradicated, is to perform a further arthroplasty or repair the recurrent hernia.

Necrotic tissue must be excised and delay only results in further deterioration of the patient. (The only common exception to this general surgical rule is pancreatic necrosis [see Chapter 20, p. 347].) A gangrenous limb can be amputated and a strangulated loop of bowel resected as a definitive procedure. The extensive soft tissue necroses seen in necrotising fasciitis (see Chapter 2, p. 23) and in a mesenteric vascular incident (see Chapter 23, p. 419) may require one or more salvage procedures to excise dead tissue, as further necrosis may occur after the initial exploration. Reconstruction can be deferred to a later operation. Similar considerations occur when, for example, the left colon sloughs after aortic aneurysm surgery or an oesophageal conduit sloughs. The initial salvage operation is excision of the necrotic tissue with establishment of a colostomy or of a temporary cervical oesophagostomy and feeding gastrostomy (see Chapter 18, p. 314). The restorative colorectal anastomosis, or the construction of an alternative oesophageal conduit, is undertaken some months later.

LEAKAGE FROM THE GASTROINTESTINAL TRACT

The two main causes for this are trauma and anastomotic leakage. In many trauma situations a single definitive operation will suffice. In massive trauma, however, the patient may be too compromised to survive the lengthy operation required. The only initial concern is to arrest haemorrhage, clear intestinal contents from the peritoneal cavity and prevent further leakage. This salvage surgery is described as 'damage control' (see Chapter 15, p. 254).

Anastomotic leaks most commonly occur at around 10 days postoperatively. Simple repair is not an option as there is surrounding infection with friable and sometimes poorly perfused tissue. Salvage relies on diversion of intestinal contents from the anastomosis, if this is possible, and surgery to restore gastrointestinal continuity is usually delayed for 6 months. Faeces can be diverted from colonic and rectal anastomoses with either a colostomy formed from the proximal end of the anastomosis or an upstream ileostomy or colostomy (see Chapters 22 and 23). Upper gastrointestinal anastomoses can be less easily excluded, but leakage can be reduced by stopping oral intake and reducing secretions with octreotide. Drainage of intestinal contents may be profuse and prolonged, and either enteral feeding, distal to the leak, or parenteral feeding must be instigated.

Following major intra-abdominal catastrophes it may not be possible to close the abdominal wall owing to increased intra-abdominal pressure and fistulae. The salvage procedure of temporary abdominal containment, or even a laparostomy, is discussed in Chapter 13 (p. 218).

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INTRODUCTION

The skin is one of the largest organs of the human body. It serves a multitude of purposes: a barrier to infection; a controller of heat and fluid loss; and a sensory interface with the world. Its aesthetic qualities are of the utmost importance to the individual. The mobility and elasticity of the skin are necessary for joint movement, and its strength essential in areas where it is subjected to repeated minor trauma, especially in the hands and feet. The skin of each part of the body is modified to suit specific purposes; for example, the thick-ridged, sensitive and moist skin of the finger tip is ideal for gripping tiny objects, while the thin, compliant skin of the eyelid provides ideal mobility and protection of the globe.

Every skin incision heals with a scar, which has the potential to cause disturbance of function or appearance. Scars are to a certain extent unpredictable. However, certain parts of the body are notorious for their propensity to form hard, red, elevated hypertrophic scars. Furthermore, the position of a scar has a great bearing on its visibility and its connotations; the preauricular face lift scar is, for example, a barely apparent trade-off for the aesthetic enhancement, whereas a scar of equivalent length only a few centimetres further forward in the mid cheek can be socially and economically devastating.

Skin incisions and suturing are often the first surgical skills acquired by a trainee. Very few operations can be performed without cutting through the skin. It may be incised to gain access to deeper structures or the surgery may be primarily on the skin itself whether for the repair of trauma or for the excision of a skin lesion. An understanding of the surgical challenges of the integument is therefore fundamental to all surgeons, even if certain techniques are the preserve of those specialising in cutaneous surgery.

SKIN INCISIONS AND SUTURES

Incisions and tissue handling

Skin incisions must be carefully planned, not only to excise a skin lesion or give good access to underlying structures but, wherever possible, they should lie in – or parallel to – the natural crease lines of the skin (Figure 2.1). Alternatively, they may sometimes be placed at a more remote site to disguise their existence. Scars should not be placed across the flexor aspect of a joint, and ideal skin incisions on the palm

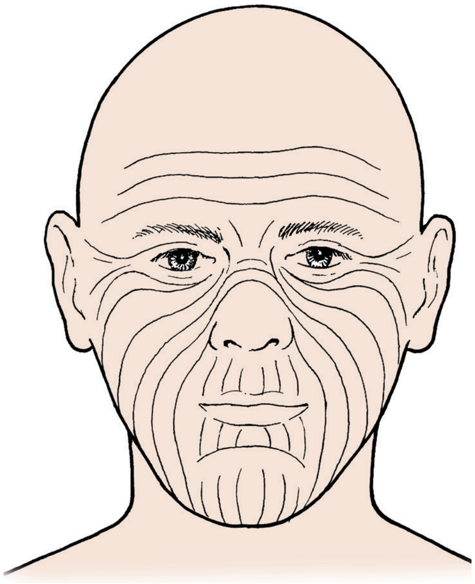

Figure 2.1 *Natural crease lines on the face.*

of the hand are shown in Figure 2.2. Surgeons will, however, encounter situations where they are forced to compromise on this counsel of perfection.

Incisions through the skin must be made cleanly with a sharp knife held at right angles to the surface. If the skin is loose and wrinkled, it should be held gently stretched or it will not cut cleanly. Diathermy incision of the skin is preferred by some surgeons as it reduces bleeding. However, there is a risk of thermal injury to the skin to the detriment of wound healing and scar quality. Therefore, although diathermy is often used for the skin incision of, for example, a laparotomy, it cannot be recommended in cosmetically sensitive areas except when used by very experienced surgeons. If diathermy is utilised for the skin, the 'cut' rather than the 'coagulation' setting must be selected to minimise thermal damage. Fine-toothed forceps and fine skin hooks are recommended when operating on the skin. Small bleeding points appear as the dermis is cut. If necessary, these may be coagulated with fine bipolar forceps. However, again there is a risk of thermal injury. In most circumstances, patience in tolerating this early bleeding will be rewarded by haemostasis. Although all living tissue must be handled gently, the effects of rough handling of the skin are more visible than that of deep tissue. As the incision continues into the subcutaneous fat, larger bleeding vessels are encountered that need to be sealed with diathermy coagulation or ligated. Bleeding from vessels that 'perforate' the deep fascia from underlying muscles can be troublesome. It is essential to control these bleeding vessels promptly before they retract. Coagulation diathermy or ligation is appropriate if they can be isolated. Alternatively a suture, or a custom-made metallic clip, may be employed.

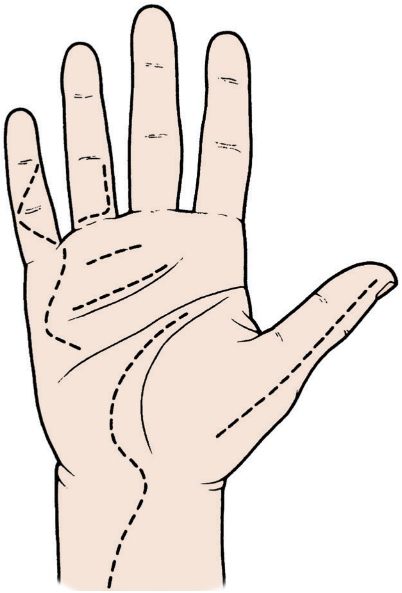

Figure 2.2 *Acceptable incisions on the palmar aspect of the hand.*

Closure of superficial wounds

Healing by first intention is a realistic expectation after most surgical and traumatic breaches to the skin if the skin edges are approximated. Grossly contaminated wounds presenting late, with possible concern over viability of deeper tissue, are obviously unsuitable for primary closure, and their management is considered in more detail in Chapter 4. More minor contamination is not a contraindication to primary closure if surgical debridement is radical. Any dirt or foreign material must be removed.

Wounds of the hand require particular attention. Blunt injuries that have produced a bursting injury with gross oedema should not be sutured as the tissue tension will be too great. Wounds of the wrist and hand are easy to underestimate. There is little subcutaneous fat and tendons and nerves are vulnerable. Often, an apparently simple skin laceration has been repaired, and only later does it become apparent that a superficial tendon or nerve has also been severed. In every hand and wrist laceration the surgeon must, before exploring the wound, check for distal function of any structure that could have been injured. Exploration for deep damage requires good operative and anaesthetic conditions, and is discussed further in Chapter 4.

Failure of primary healing in a sutured skin wound is usually due to a collection of serosanguineous fluid or blood in the subcutaneous fat. This has often collected because of failure to obliterate a dead space, combined with suboptimal haemostasis. Rough handling may have devitalised some of the tissues and any minor contamination then results in an infected collection. The potential dead space in the subcutaneous fat may be obliterated by the skin suture (Figure 2.3a), or a separate absorbable suture can be used to appose the fat. The latter is more successful in areas where there is a membranous layer to the superficial fascia, as in the groin. In many instances the subcutaneous fat, although thick, lies in apposition and no further action is needed other than careful haemostasis. The routine use of surgical drains in subcutaneous fat is being challenged in many areas of surgery. However, there are situations where most surgeons would recommend vacuum drainage of the subcutaneous fat for 24–48 hours, or for longer periods if drainage is significant. A potentially large dead space, for example as after the removal of a large lipoma, is one such instance. A drain may also be beneficial when bacterial contamination of the wound has occurred in colonic surgery, as even a small collection of blood in the subcutaneous fat is likely to become infected.

After dealing with the subcutaneous fat, the skin edges must be held in accurate apposition and supported for as long as it takes for the scar to develop the tensile strength necessary to protect against distraction.

Interrupted skin sutures may cause scarring, especially if the sutures are too tight and postoperative tissue swelling causes them to cut into the skin. Vertical 'mattress sutures', used to evert the skin edges, have even greater potential to scar the skin if they are drawn too tight (Figure 2.3b). Interrupted skin sutures should be of a fine smooth non-absorbable material such as nylon or polypropylene (Prolene™), which causes less tissue reaction than silk. Cutting needles are required for skin. The needle should be passed perpendicularly through the skin and the stitches tied with only sufficient tightness to bring the skin edges together without constriction. Knots should be placed laterally away from the wound. Tight sutures cause ischaemia, delay healing and increase scarring. The intrusive cross-hatched scars associated with interrupted sutures are a result of suture-induced ischaemic necrosis. An interrupted suture closure can give excellent cosmetic results on the face, where sutures should be removed at around 5 days. Epidermal downgrowth of spurs occurs around suture material left *in situ* for over a week and results in small punctate scars. As the skin in most areas of the body requires the support of sutures for the healing wound for at least 7 days, these little punctate scars may be unavoidable. Below the knee, and on the back, sutures are needed to prevent skin dehiscence for around 2 weeks.

A continuous subcuticular suture to appose the dermal layers of the skin is a fast and cosmetically satisfactory method of skin closure (Figure 2.4). The additional scarring from sutures is avoided, but it should be noted that a subcuticular suture gives no support to the underlying tissue. Synthetic absorbable materials are frequently used by surgeons to close incisions. However, these can cause a tissue reaction and may in some cases be blamed for poor scars: the tissue reaction induced by catgut was sufficiently severe to preclude its use as a subcuticular suture. Therefore, when selecting suture material for subcuticular use, a monofilament synthetic suture that causes minimal reaction, such as Monocryl®, is recommended. Any knots of absorbable suture should be placed deep and well away from the wound edge. A non-absorbable nylon or Prolene™ subcuticular suture avoids the tissue reaction associated with absorbable sutures and is removed after 10–14 days. The needle is introduced beyond one end of the wound and, after completion, is brought out beyond the other end. Steristrips can be used to provide support and to secure the suture. A crushed bead on the suture will also secure it, but has the disadvantage that such beads prevent any suture material being drawn into the closure as the wound swells postoperatively, and thus the beads are pulled into the skin, causing discomfort and, occasionally, additional scarring.

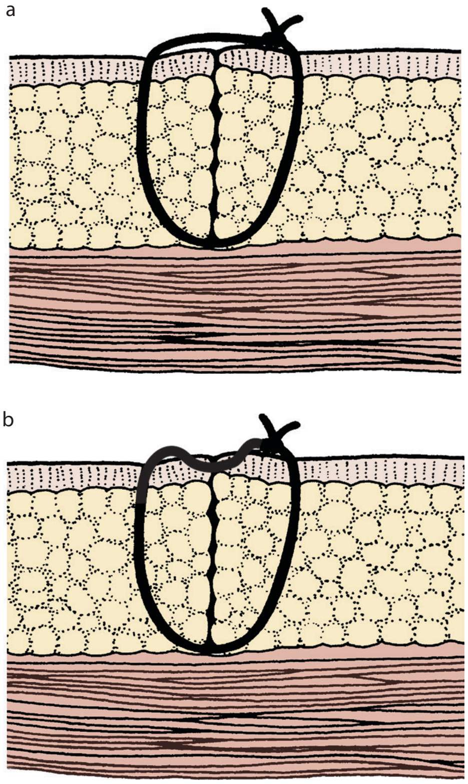

Figure 2.3 *(a) A simple suture securing apposition of skin and underlying fat. (b) A vertical mattress suture.*

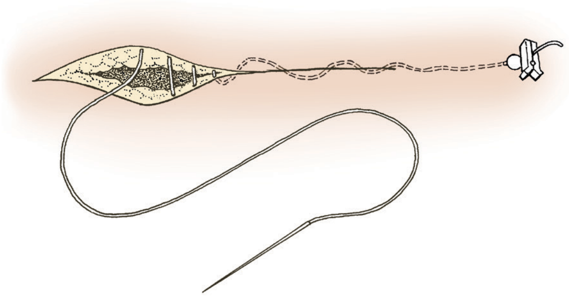

Figure 2.4 *A subcuticular non-absorbable suture should be of a smooth material such as Prolene™ for easy removal, and the ends are brought out beyond the wound. If an absorbable suture is used, the ends are secured by buried knots.*

Skin clips, steristrips and tissue glue can also be used for skin closure in certain circumstances. If clips are used, they should be removed early as they can be associated with cosmetically unacceptable cross-hatching of the scar.

SURGERY FOR SKIN LESIONS

Surgical removal of benign tumours and other skin lesions is often requested purely on cosmetic grounds. Alternatively, there may be recurrent infection, bleeding or pain making removal desirable. The patient or the surgeon may be concerned about malignancy. Before embarking on cosmetic excisions surgeons must be confident that the scar will be less conspicuous than the original blemish and they should also consider the natural history of the lesions. For example, disfiguring cavernous haemangiomata may enlarge dramatically in late infancy and are self-limiting, and the results of surgical intervention are usually worse than the results of natural regression. The differential diagnosis of skin lesions is beyond the scope of this chapter, but many simple excisions can be avoided if the patient can be confidently reassured that a lesion is benign. Accurate clinical diagnosis is therefore important.[1] Cooperation with a dermatologist is invaluable for this and for the management of those skin lesions better treated by curettage, cryotherapy or topical applications.[2] Lasers also have a valuable role in the management of certain skin lesions such as capillary malformations and café-au-lait macules.

Anaesthesia

Local infiltrative anaesthesia with lidocaine is suitable for most minor superficial operations. Lidocaine is generally available as 1 or 2 per cent solutions. A 0.5 per cent solution is equally effective and, if unavailable, can be made by dilution of the above strengths with normal saline. The recommended maximum dose of lidocaine is 3 mg/kg bodyweight. Thus, for an average 70-kg man the surgeon may use only 10 ml of a 2 per cent solution but 40 ml of a 0.5 per cent solution. The more dilute solutions therefore have advantages when more extensive surgery is planned. Lidocaine with adrenaline (epinephrine) is suitable for local infiltrative anaesthesia, except in the vicinity of end arteries where arterial spasm could endanger blood supply and, in particular, it should be avoided in a finger or toe. An adrenaline-containing local anaesthetic agent has several benefits. The arteriolar constriction reduces small vessel ooze during surgery and also slows the absorption of local anaesthetic agent into the circulation. This gives both a longer period of anaesthesia and allows a higher dose to be used before there is concern over systemic toxicity. Proprietary solutions contain 1 part adrenaline in 200,000. Local anaesthetic agents are introduced into the subcutaneous fat as shown in Figure 2.5. If the injection is close to the skin the delay before anaesthesia is minimised, but if it is injected intradermally, although effective, the initial injection is more painful. It should be remembered that the skin will require to be anaesthetised wide of the incision to include the skin through which the sutures are to be placed. As the solution is injected the point of the needle is slowly moved, thus minimising any risk of significant intravenous injection. Aspiration before injection is only necessary when a large volume of local anaesthetic agent is injected at one site. To anaesthetise a large area of skin, the needle may have to be introduced at multiple points.

Bupivacaine (0.5% and 0.25% solutions with and without adrenaline) is a longer-acting local anaesthetic agent. Its onset is slower than lidocaine, but its effectiveness for up to 8 hours is useful for postoperative pain relief.

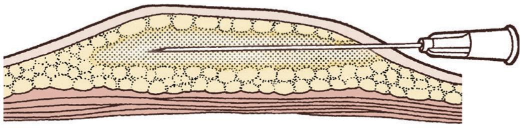

Figure 2.5 *Subcutaneous infiltration of a local anaesthetic agent.*

A local anaesthetic agent may be used around a nerve to give anaesthesia in the area supplied by the nerve, a so-called nerve block. A digital nerve block is commonly used for surgery on a digit. Lidocaine *without adrenaline* is injected on either side of the finger around the dorsal and palmar digital nerves. It can be injected as shown in Figure 2.6 or more proximally into the web spaces. Other common nerve blocks include brachial, intercostal, ilioinguinal and femoral blocks.

Subcutaneous fat has very few nerve endings, and a large subcutaneous lipoma can often be removed painlessly with the local anaesthetic only infiltrated just beneath the overlying skin. However, if a cutaneous nerve that has not been anaesthetised is encountered, severe pain may ensue.

Infiltration of a local anaesthetic agent is painful. The pain can be minimised by warming the solution, adding bicarbonate to render it less acidic, injecting slowly with a fine-gauge needle, prior topical application of local anaesthetic creams such as EMLA (a combination of lidocaine and prilocaine), infiltrating areas of looser tissue first and by performing local nerve blocks prior to more extensive infiltration. However, pain is always worse in an anxious patient and gentle reassurance can also minimise distress.

Excision of a benign skin lesion

An ellipse of skin is excised so that a linear closure can be effected (Figure 2.7a); the long axis of the ellipse should ideally be in, or parallel to, the natural skin creases. The width of the ellipse should be such that the lesion is fully excised plus a small margin of macroscopically normal skin. The resultant scar is thus seldom shorter than three times the diameter of

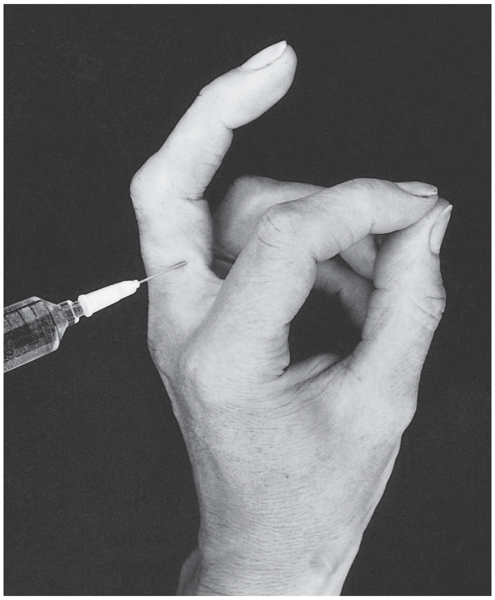

Figure 2.6 *Digital nerve block anaesthesia.*

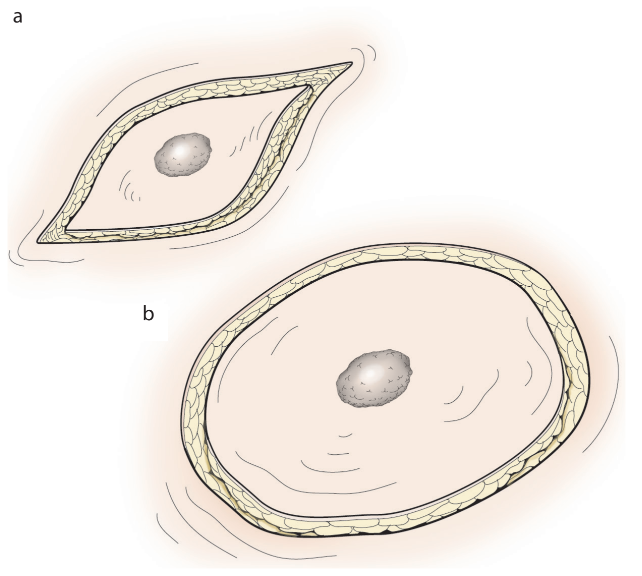

Figure 2.7 *Excision of skin lesions. (a) An elliptical incision is most suitable if a linear closure is planned. (b) A circular or oval incision is more appropriate if a skin graft is planned.*

the original lesion. Underlying subcutaneous fat may have to be included in the ellipse if the lesion extends into it. In other instances, fat underlying the excised skin ellipse must be excised to allow the skin edges to be brought together without tension. Haemostasis and closure of the defect are performed as discussed above.

Excision of a malignant skin lesion

The three most common skin cancers have different behaviour patterns and thus pose different challenges for the surgeon.

BASAL CELL CARCINOMA (RODENT ULCER)

This is the most common malignant skin tumour. It is slow-growing and metastases are extremely rare, but if left untreated it may penetrate deeply and erode into soft tissue and even into bone. The excision should be planned to include at least 3 mm of normal tissue on all aspects, including the deep surface. The microscopic edge of the tumour may be wide of the clinical edge, and histology is important to check the completeness of excision, especially at the deep margin. Complete excision is associated with a recurrence rate of less than 2 per cent. A technique of excision in layers, with horizontal frozen section control, was originally described by Mohs. It is not used widely for primary basal cell carcinomas but it may have advantages for recurrent lesions, and for those close to sensitive structures, in ensuring complete tumour removal.[3] It is not a technique that can be recommended for general surgical practice. Penetrating tumours around the eyes, nose, mouth and ears can pose major surgical problems, requiring skilled reconstruction following excision. This is considered in more detail both later in this chapter and in Chapter 11. Radiotherapy can also be used to treat these difficult lesions, but scarring still occurs and cosmesis may be no better. In addition, radiotherapy is contraindicated in certain areas, for example the pinna and close to the lacrimal canaliculi.

SQUAMOUS CELL CARCINOMA

This tumour may arise in normal skin, but areas damaged by chronic traumatic or venous ulceration, or by solar exposure, are at increased risk. The tumour is sensitive to radiotherapy, which may be used as an alternative to surgical excision in some sites. Carcinoma in situ may extend beyond the visible lesion and excision to include a margin of 1 cm of macroscopically normal skin is recommended. Advanced tumours metastasise to regional nodes. The multiple superficial tumours of sun-damaged skin appear to be a less aggressive subgroup. Surgery for squamous cell carcinoma of the lip and pinna are discussed further in Chapter 11.

MALIGNANT MELANOMA

This is the most aggressive of the skin cancers. Tumour thickness and depth of penetration are major determinants of survival[4,5] as metastatic spread is increasingly likely with thicker tumours. A wider excision is recommended than for other skin malignancies as there is a real risk of local recurrence in the skin and subcutaneous tissue adjacent to the scar. This risk is also related to tumour thickness, and recommended clearance margins for excision are based on the thickness of the melanoma.[6] The very wide excisions previously performed have, however, been shown to be unnecessary, and a 1-cm margin of normal skin around tumours of less than 1 mm in depth has been demonstrated to be sufficient. Between 1 and 2 mm the evidence is open to interpretation, and a margin of between 1 and 2 cm is normally accepted. A 2-cm clearance is recommended for lesions between 2 and 4 mm in depth. Thus, a 3-mm thick tumour requires a margin of 2 cm of normal skin. Assuming that the tumour itself is 1 cm in diameter, the width of the ellipse needs to be 5 cm. The excision should be carried down to, but not through, deep fascia to achieve optimum clearance margins in the deep plane. Excision of the underlying subcutaneous fat has the additional advantage that it may reduce the tension on a primary closure, but in many areas of the body simple closure is not possible and skin grafting or flap reconstruction is required. Reconstruction with a flap may be cosmetically preferable. The limb proximal to a melanoma is avoided as a donor site for a skin graft for fear of encouraging the development of recurrent melanoma skin nodules within it.

Preoperative decisions in potential malignant melanomata are difficult, especially as clinical diagnosis is far from infallible. Lesions that appear benign clinically are excised and the diagnosis of malignant melanoma is only made at histological examination. Conversely, many surgeons have experience of a patient who has had a wide excision with the inevitable challenge of skin closure and scarring, only to find that the confident clinical diagnosis is not confirmed histologically. Malignant melanomata may arise in normal skin, from within a pre-existing benign naevus or from a single area of an in-situ lentigo maligna. The tumours vary in appearance and although dark pigmentation is usual, amelanotic lesions also occur. Even if a confident diagnosis is made preoperatively, the estimation of thickness is uncertain, especially if it has arisen from the edge of a pre-existing benign naevus. Fortunately, an initial excision followed by a wider clearance is not detrimental and is thus the surgical management of choice for most suspicious lesions. If a suspicious lesion is excised under local anaesthesia with a 2-mm clearance, urgent paraffin section histology will give a firm diagnosis and an accurate measurement of the thickness of the lesion. This will allow definitive further surgery, if indicated, to be planned a few days later. Incision biopsies or frozen-section histology are seldom helpful. A minimal excision biopsy margin ensures tension-free healing and also maintains the local lymphatic drainage patterns. This is important if a subsequent sentinel node biopsy (SNB) technique is to be employed.

At definitive surgery, when grafting or flap reconstruction is planned rather than linear closure, a more rounded ellipse or circle of tissue is excised (Figure 2.7b). Malignant melanomata around, or under, a nail often require at least partial amputation of the digit to achieve the necessary local clearance and skin cover.

The spread of malignant melanoma occurs by both lymphatic and haematogenous pathways, and there has been much debate over the years regarding the potential benefit of *prophylactic* radical excision of the draining lymph nodes. More recently the debate has focused on the merits of SNB to guide this decision.[7] If a radical prophylactic excision is undertaken and the nodes are tumour free, the operation has been unnecessary and carries significant morbidity. If nodes are positive, it may still have been unnecessary if haematogenous spread has already occurred, as death from distant metastases may precede symptoms from the regional nodes. Theoretically, however, there may be a few patients in whom the surgery might prevent further spread. The most accurate method of identifying nodal metastases, prior to a full nodal dissection, is by an SNB. A randomised trial (Multicenter Selective Lymphadenectomy Trial 1 – MSLT 1) aimed to evaluate the potential survival benefit of patients undergoing SNB (and radical dissection if SNB was positive) against nodal observation (and radical dissection upon detection of clinically palpable nodes). While there was no difference in disease specific 5-year survival between the groups (86.6% versus 87.1%), patients in the observation group who subsequently developed lymphadenopathy and had a delayed dissection had significantly worse 5-year survival than those who had a positive SNB and early node dissection. There are therefore ongoing clinical trials to evaluate whether SNB alone can provide a survival advantage (MSLT II).

While most people accept that SNB is the most accurate way to detect nodal metastasis in melanoma, there is still debate as to whether it has a role in improving survival. Hence there is wide variation on if, and how, SNB should be incorporated into clinical practice.[8]

Sentinel node biopsy

SNB is based on the premise that if there is no metastasis in the first drainage node (sentinel node), then the risk of any further nodal metastases is so low as to make a radical lymphadenectomy unjustified. The technique is currently mainly employed in malignant melanoma and in breast cancer. Two methods of identification of the sentinel node have been developed, but most surgeons now favour a combination of the two. Radiolabelled colloid or vital dye is injected into tissue adjacent to a primary tumour, on the premise that the lymphatic drainage of the peritumoural tissue will be identical to that of the tumour itself. The sentinel node is then identified by the concentration of the isotope, as shown by scintigraphic images or hand-held gamma ray probes, and also by the concentration of blue dye, as seen at operation. Timing is of great importance, as the clearance of the two substances differs. Radiolabelled colloid is slow to reach the regional nodes, but once there remains concentrated in the sentinel node. Vital dye, in contrast, reaches the sentinel node within 5–10 minutes and then rapidly drains on into further nodes.

In melanoma surgery, radiolabelled colloid is injected around the biopsy site the day before surgery, and a subsequent preoperative scintigraphic scan will identify the position of the sentinel node. This is of particular help in planning surgery when it is not immediately apparent to which nodal group the lymphatics of the tumour drain. Nodal dissection can be guided by a hand-held gamma ray detector, but accuracy is increased if blue dye is also injected intraoperatively. At around 10 minutes after injection there should be one intensely stained node, which is excised for histology. The surgery of lymph nodes is discussed further in Chapters 3, 10 and 25.

Radiotherapy has no place in the treatment of primary melanoma but can be valuable for the treatment of intracranial or spinal metastases. Systemic chemotherapy has been disappointing and its use is only advocated in advanced disease. Combinations of chemotherapy with interferon-α or interleukin-2, or both, have failed to show significant survival benefits but there is significantly increased toxicity, which has precluded their use outside of clinical trials. Melanoma vaccines have shown positive early results and are currently being evaluated in phase III clinical trials.[9]

Excision of a sebaceous cyst

Excision of sebaceous cysts is recommended as they enlarge, often become infected and seldom regress spontaneously. It is important to excise them completely in order to prevent recurrence. They arise from the deep layers of the skin and are most satisfactorily excised in a similar manner to that used for other skin lesions, through an elliptical incision. The punctum, where the overlying skin is tethered to the cyst, should be in the centre of an ellipse. The length of the ellipse approximates the diameter of the cyst. The width of the ellipse is determined by planning the skin closure, and will vary with the degree of skin stretching that has occurred. For example, a sebaceous cyst on the scalp is protuberant with stretched overlying skin and a wide ellipse is removed. Sebaceous cysts on the back lie mainly in the subcutaneous tissue with minimal stretching of the overlying skin, and only a narrow ellipse of skin need be removed.

First the skin ellipse is incised, with care taken not to enter the cyst with this initial incision. The plane is then developed immediately outside the cyst wall. This plane can be difficult to enter, especially where stretched skin is closely applied to the cyst wall. It is often easier to dissect initially at the two ends of the ellipse, ensuring that the skin incision is full thickness into subcutaneous fat. Artery forceps applied to the freed ends of the ellipse and a skin hook placed under the lateral skin edge can be used to retract and counter-retract to identify the plane (Figure 2.8) and place it on stretch for sharp dissection as described in Chapter 1. Blunt dissection, with forceps or scissors, is also frequently employed but if there is scarring across the plane from previous inflammation, the cyst wall frequently tears.

An alternative method of cyst excision can be utilised to minimise cutaneous scarring. Instead of excising the cyst unruptured, the cyst is deliberately punctured by driving a 3–4-mm punch through the overlying skin and superficial cyst wall. The contents are expressed and the cyst wall is then teased out through the skin opening. The resultant wound is relatively small and can be closed primarily or left open to heal by secondary intention, with a pleasing cosmetic outcome.

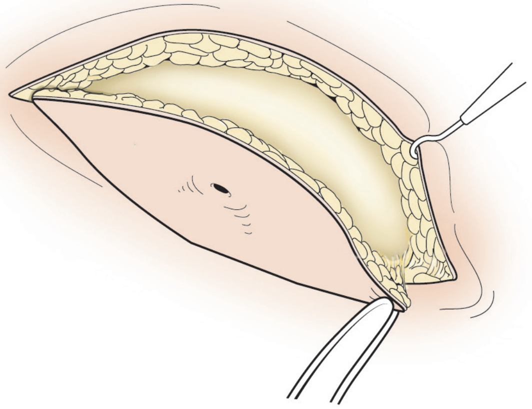

Figure 2.8 *Excision of a sebaceous cyst. The artery forceps on the freed corner is useful for retraction as the lateral skin edge is lifted initially with a skin hook.*

If any inflammation is present, removal of the cyst should be deferred until this has subsided. A frankly infected sebaceous cyst should be simply incised and the contents drained. No attempt should be made to excise it, as wound complications and disappointing scars are often the result. In addition, the infection frequently destroys the lining of the cyst and no further treatment may be necessary. If the cyst does recur, excision can be planned at a later date.

SURGERY OF THE FINGER- AND TOENAILS

If a fingernail or toenail is avulsed, the nail regrows from the nail bed. Avulsion can therefore only be a good surgical option for a self-limiting condition. For example, trauma to a digit – with the associated soft tissue swelling – can result in a previously trouble-free nail growing into the oedematous tissue of the nail fold and causing further damage and infection. The curved nails that cause ‘ingrowing toenails’ are really only a chronic variant of this, as the condition is almost unknown in barefooted people. Avulsions to allow the infection to settle may be successful if patients are prepared to adapt their nailcutting and footcare when the new nail regrows. A nail may also be avulsed to examine – and even biopsy – a dark stain under a nail when there is doubt as to whether this is a haematoma or a malignant melanoma. If, however, there have been recurrent problems with an ingrowing nail, or a nail is thickened with onychogryphosis, the nail bed must be removed or destroyed, otherwise the problem will simply recur as the nail regrows. The nail bed may be excised using a Zadek’s operation (Figure 2.9) or it can be destroyed with phenol.

General anaesthesia or a digital block is suitable for toenail surgery, and a toe tourniquet will give a bloodless field. Bleeding can obscure the anatomy in a Zadek dissection and it will displace the phenol during phenolisation. The nail is first avulsed. One blade of a heavy artery forceps is introduced under the nail, either in the medial or the lateral third. Rotation of the closed forceps lifts the medial or lateral nail edge out of the basal corner and the nail fold (Figure 2.9a). The manoeuvre is repeated on the other side and the whole nail avulsed. The tissue overgrowth and proud granulations are curetted or excised from the nail folds. The raw nail bed is dressed with tulle gras and absorbent dressings and a crepe bandage. The distal pulp skin should be visible beyond the dressing so that adequate perfusion can be confirmed.

To excise the nail bed two incisions are made out from the basal corners and the flap of skin overlying the base of the nail bed is elevated (Figure 2.9c). The germinal area of the nail bed is dissected out, paying particular attention to the medial and lateral extensions, which are loosely attached to the bony expansions at the base of the proximal phalanx. This is not, therefore, a suitable operation if there is sepsis, as there is a risk of spreading the infection into the bone or joint. An infected ingrowing nail should be avulsed and the excision of the nail bed postponed for around 6 weeks, by which time all infection should have settled. It is also important to be aware that excision should not be combined with phenolisation, as the phenol damages the joint capsule if the excision is already complete. At the end of a Zadek excision the medial and lateral corner extensions of the germinal matrix should be checked for completeness (Figure 2.9d). An artery forceps, inserted into the excised lateral corner, will only pass out through it if excision has been incomplete. Regrowth from germinal matrix left *in situ* can result in recurrent nail spicules. The incisions **WX** and **YZ** are closed with a suture, and the raw tissue of the nail bed is dressed with tulle gras and absorbent dressings.

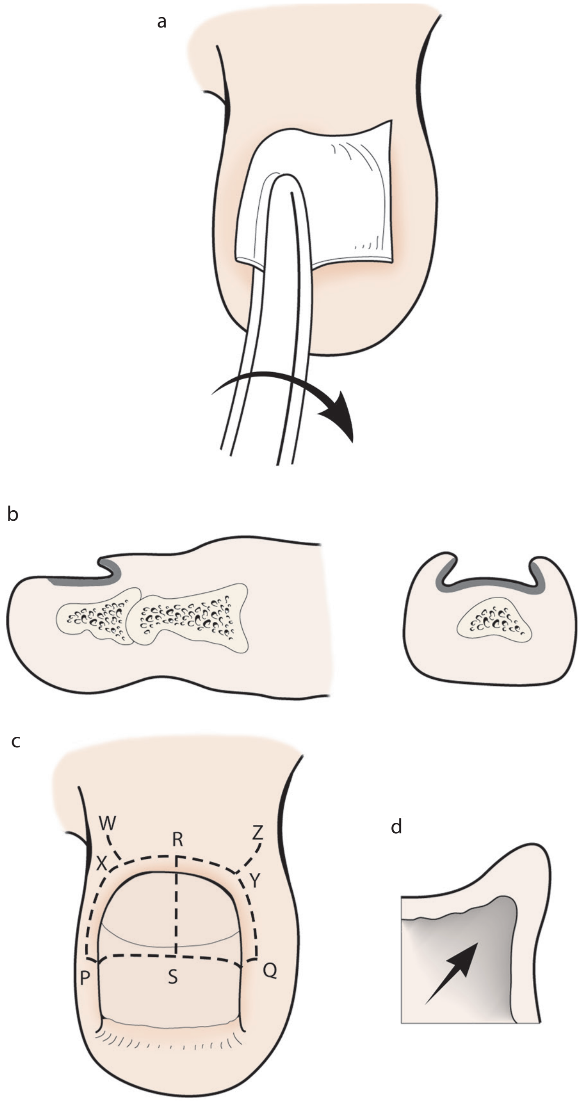

Figure 2.9 *Zadek's nail bed excision. (a) The medial edge of the nail has been avulsed and the forceps is in place to avulse the lateral edge. (b) The germinal matrix of the nail is in the proximal third of the nail bed. It extends under the skin fold at the base of the nail and laterally under the skin at the edge. In the basal corners there is often a significant extension (d). (c) The incision **WXYZ** is made and the flap elevated to expose the basal germinal matrix. The incisions **XP** and **YQ** then allow retraction of the lateral skin folds. The incision **PQ** is distal to the half moon on the nail bed, which indicates the end of the germinal portion. The whole area of germinal matrix is then excised, but this is easier after it has been divided into two lateral halves by the incision **RS**. Both **PQ** and **RS** are incisions through the whole thickness of the germinal matrix. In the corners the germinal matrix extends further than is often appreciated (as far as **Z**). (d) A complete specimen of germinal matrix. An artery forceps inserted into the corner should not protrude out through a defect.*

Immediate phenolisation after avulsion is safe in the presence of infection and avoids the necessity of a second procedure. Phenolisation must be carried out with great care in order to avoid burns to surrounding tissue. Aqueous phenol crystals are used and melted over hot water. After 3–5 minutes of contact with the germinal nail bed, the phenol is neutralised with alcohol. The nail bed is then dressed in the standard fashion. Healing is slow as this is a chemical burn.

Recurrent nail growth may be a problem with either method but can be largely avoided by meticulous technique. Some patients with ingrowing toenails are anxious to retain a toenail. It is possible to avulse only a lateral or a medial third of the nail and then to excise or destroy only that area of germinal matrix. Unfortunately, the original problem may recur at the new edge of the nail and many of these patients will finally need a full nail bed ablation.

EXCISION OF A LIPOMA

Lipomata are the commonest tumours of the subcutaneous tissue and excision is only indicated if they are painful or large and unsightly. A rapid increase in size occasionally causes concern that the tumour might be a sarcoma. A linear incision through the overlying skin is deepened through the overlying fat until the surface of the lipoma is reached. It can be distinguished from the surrounding fat by a slightly different colour, and the fatty lobules are larger. In addition, there is a suggestion of a fine transparent 'capsule'. A lipoma can be shelled out using *blunt dissection*, and this is often the most appropriate method. Alternatively, a *sharp dissection* can be used to cut the fine areolar tissue put on stretch between the lipoma and the surrounding fat (Figure 2.10). Even a large lipoma can be easily excised under local anaesthesia unless it is clinically adherent to the underlying muscle. The plane on the edge of a lipoma will be clear of subcutaneous vessels and

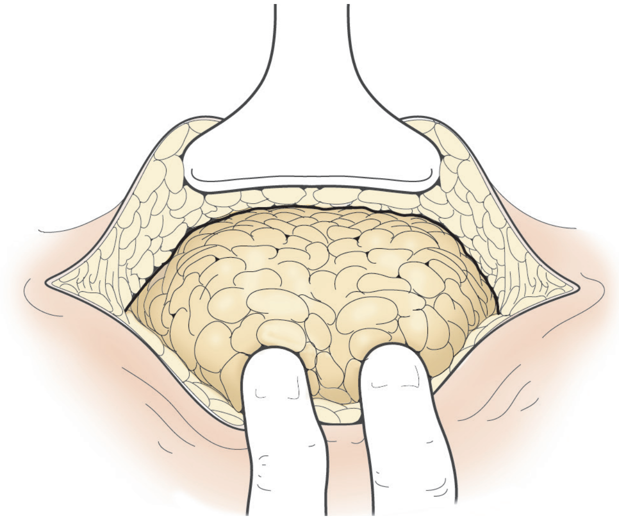

Figure 2.10 *Retraction, with counter-traction, demonstrates the fine strands of areolar tissue that are all that cross the plane between a lipoma and the surrounding fat.*

nerves, and very little in the way of nerves or vessels enters the lipoma. A lipoma that is clinically adherent to underlying muscles has extensions tracking deep between muscle bellies, often around small vessels and nerves entering the lipoma. This is a particular problem in lipomata on the back of the neck, and not only explains the aching and shooting pains sometimes associated with these lesions, but can also make their removal under local anaesthesia very challenging. The closure of the subcutaneous tissue and skin is discussed above.

If histology shows the presence of a liposarcoma, a re-excision should be undertaken to include the scar and a margin of the surrounding tissue in order to prevent local recurrence.

The use of liposuction to treat lipomata is controversial. Although often efficacious, the small risk of misdiagnosis, and inadvertent liposuction of a malignancy, is cause for concern.

SURGERY FOR SKIN LOSS OR DESTRUCTION

Skin may be lost by direct mechanical trauma or irretrievably damaged by pressure, ischaemia, heat, chemicals or infection. The final pathway of treatment in all of these situations is the subsequent restoration of skin cover by surgical means.[10] Early excision of obviously dead skin reduces the risk of secondary infection and, in conditions such as extensive burns, is associated with improved survival and outcome. It is therefore no longer regarded as advisable to watch and wait as skin sloughs. In an appropriate setting, early excision is more often the treatment of choice. However, in the two situations below, early surgery to dead skin is mandatory.

Constricting eschars

Thermal and chemical burns may cause full-thickness destruction so that the skin is replaced by a hard, constricting eschar. If this is circumferential on a limb or the chest it may threaten the distal circulation or prevent adequate respiratory movement. Such eschars require early linear incision down to live tissue to allow release of the constriction.

Necrotising infections

Here, the progressive skin destruction is often only arrested by surgery. Although bacterial in aetiology, antibiotics alone are ineffective as tissue death is occurring ahead of bacterial colonisation by the combined effects of cytotoxic bacterial toxins and ischaemia secondary to small vessel damage. Antibiotics do not penetrate dead tissue. *Fournier's gangrene* and *necrotising fasciitis* are examples of this process. As soon as the diagnosis is suspected, the extent of the damage must be explored under general anaesthesia, and the patient forewarned of the extensive nature of the surgery that may be required. In necrotising fasciitis an apparently localised abscess, which may have been explored locally a few hours before, is associated with extensive death of fascia, subcutaneous fat and overlying skin. The patient may be extremely unwell and require intensive care support in addition to antibiotics, but the only chance of a cure is complete excision of all the dead tissue.[11] Fortunately, tissue deep to the deep fascia is normally spared. Extensive reconstruction is postponed until the infection is under control and the patient's general state has improved.

Necrotising infections of muscle are discussed in Chapter 4.

Reconstructive procedures

Not every wound can be closed directly, especially after skin has been lost by trauma or surgical excision. If direct suture without tension is impossible, then a range of choices is available. The simplest effective measure is usually the best, but the long-term cosmetic result should be considered. Many of these procedures are suitable for general surgeons, but some will yield poor results to an occasional operator. If extensive reconstruction is anticipated, especially on the face, the help of a plastic surgeon is essential if at all possible.

SIMPLE UNDERMINING AND ADVANCEMENT

Careful undermining of the adjacent tissues away from the edge of a wound may permit primary closure without tension. The level at which this undermining should be carried out is important. In the face, undercutting must be close to the skin to avoid branches of the facial nerve. In the limbs and trunk, the most suitable plane is on the deep fascia, while on the scalp the best plane is between the galea and the pericranium (Figure 2.11). Carefully placed parallel incisions to the undersurface of the galea may allow further advancement without tension. If skin closure is not possible even after undermining, skin grafting should be considered, along with any possible benefit in opting for a flap technique instead.

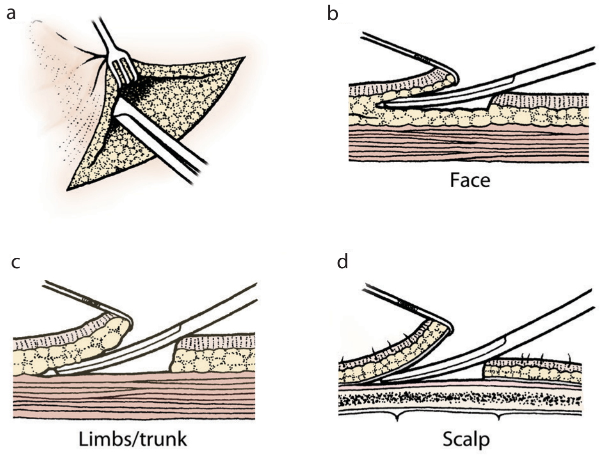

Figure. 2.11 *Undermining of skin edges can reduce tension on a suture line. The general technique is shown in (a). The optimum depth for this undermining varies in different parts of the body (b–d).*

SKIN GRAFTING

Grafts are completely detached from their origin and, to survive, must obtain adequate nourishment from the bed on which they are placed.

Split-skin grafts

These are the general purpose grafts most frequently used. They can be taken from any part of the body, but the commonest donor site is the lateral surface of the thigh. The grafts may be harvested at different depths. Thin grafts, consisting of little more than epidermis, are used mainly to cover granulating areas where the urgent need is for wound healing. They 'take' well, even in the presence of infection, but their inability to withstand wear and tear and their tendency to contract relegate them to the category of temporary grafts that will need later replacement by thicker grafts or flaps. Thicker grafts contain more dermis and are far more durable and cosmetically acceptable. Indeed, the thicker split-skin grafts are almost indistinguishable from a full-thickness graft. However, the surgeon must be careful to select an unobtrusive donor site, as the thicker the skin graft the more unsatisfactory may be the healed donor area.

PREPARATION OF THE RECIPIENT AREA

A clean, freshly made 'tidy' wound (whether surgical or traumatic) presents no problems, provided that complete haemostasis is secured, preferably with bipolar diathermy coagulation. The base of the wound should be as even as possible and any spaces between muscle bellies obliterated by a few interrupted fine sutures. If ideal conditions are not met, it is possible to store skin grafts for a limited period of time (see below) and apply them to the wound at a later date.

By contrast, 'untidy' wounds and granulating areas may require careful preparation. Adherent slough must be excised and any crevices in the granulating area removed by scraping away the exuberant soft granulations. Regular wet dressings, soaked in saline or an antimicrobial solution, can be applied until a healthy, pink, flat granulating surface is produced. The process of establishing a healthy granulating bed can be accelerated by the use of negative pressure wound therapy (V.A.C. Ulta™), where a foam dressing is placed under negative pressure by a suction device. The fitness of the wound for grafting is probably best judged by the clinical appearance, as the information obtained by bacterial investigation is not always helpful and may be misleading. Complete sterility is usually unobtainable, and is not essential. However, the presence of β-haemolytic streptococci group A is a contraindication to grafting and must be treated first with systemic antibiotic therapy. A heavy growth of any pathogenic organism can interfere with the graft 'take', and frequent dressings – possibly containing an antibacterial agent such as povidone iodine – may first be required to reduce bacterial colonisation. The indiscriminate local application of antibiotic powders, solutions and creams or various desloughing agents (enzymatic, chemical or hydrophilic) is an extremely expensive and largely worthless substitute for a good dressing technique.

In the operating theatre, a healthy granulating area requires little extra preparation other than cleansing with povidone iodine or chlorhexidene (Hibitane), followed by saline. If some of the granulations are still exuberant and unhealthy in appearance, they should be scraped away and bleeding controlled with moist warm packs.

CUTTING AND PREPARING THE GRAFT

The donor site, which should have been shaved if hairy, is simply prepared like any other operation site. Grafts can be harvested with a hand-held knife, but more consistent results are achieved with a powered dermatome device. The blade of the knife and the donor site are smeared with a lubricant such as liquid paraffin. The limb should be held firmly by the assistant, whose hands provide counterpressure from behind to present the surgeon with a flat surface from which to cut the graft. The surgeon creates tension on the donor site just in front of the skin-grafting knife, with either a swab or a wooden board (Figure 2.12). A hand-held skin-grafting knife is pressed firmly against the skin and, with a steady to-and-fro sawing motion, the knife and skin grafting board move steadily forwards (Figure 2.12b).

Although the blade in the knife has been set at a predetermined depth, the thickness of the graft is also influenced by the pressure applied to the skin and the angle of the blade. The surgeon must check the thickness of the graft as he or she cuts it. This can be judged by the translucency of the

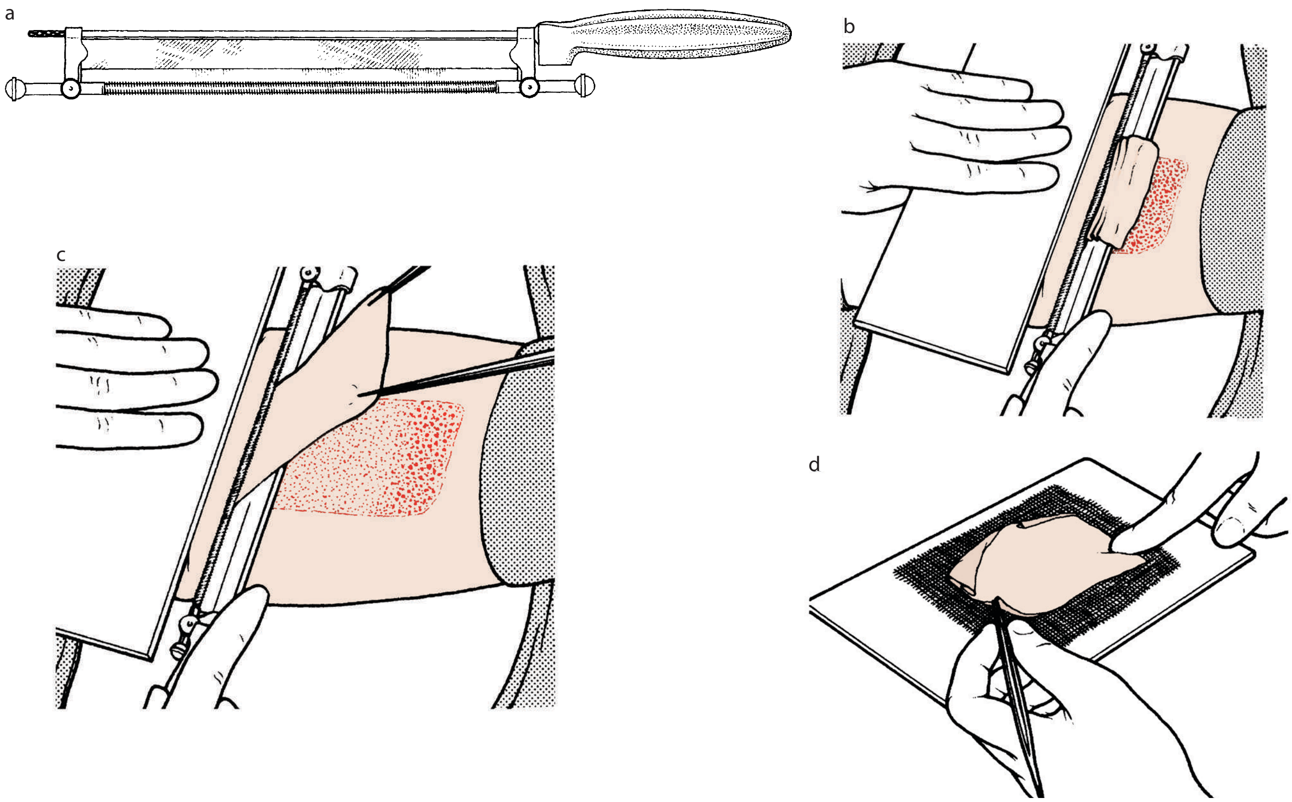

Figure 2.12 *(a) A skin-grafting knife. (b) The method of cutting a split-skin graft. (c) The pattern of bleeding is an indication of the thickness of the graft that has been taken. (d) The graft is spread out on tulle gras dressing.*

graft and the pattern of bleeding and appearance of the donor site. A very thin graft is translucent, so that the knife blade will appear bluish grey in colour through it and the bleeding points on the donor surface will be closely packed and confluent. A thicker graft will appear white in colour and the bleeding points on the donor surface are few and far apart (Figure 2.12c). If the skin graft has been cut at too deep a level and subcutaneous fat appears, the surgeon has two choices: (1) to resuture the graft in place and take a thinner graft elsewhere; or (2) to use the thick graft as a full-thickness graft and place a thin split-skin graft on the unintentionally deep donor site. The donor site should be dressed as soon as the grafts have been cut. A variety of dressings may be used, but these should be adhesive in order to avoid slide and semi-permeable to avoid collection of exudate. Inner dressings should be covered by absorbent dressings and crepe bandaging, and should be left undisturbed for at least 10 days.

The use of a graft in its unmeshed state provides the most acceptable cosmesis. However, if extensive grafting is required – as after major burns – the graft may be *meshed* to expand it and make the most economical use of the available skin. It may be passed through a meshing device (Figure 2.13) in which the mesh size is related to the degree of expansion of the skin graft and is determined either by the plastic board utilised as a carrier for the meshing machine or by the offset of the blades within the machine. A ratio of 1.5:1 expansion of the graft provides minimal expansion, but improves the ability of the graft to conform to an irregular bed and allows serum or blood to exude. Ratios of 3:1 or even 6:1 can be used for more extensive burns. If a mesher is unavailable, the graft can be 'fenestrated' by cutting slits in it with a knife while it is lying on a wooden preparation board. In extensive burns, stored cadaveric graft can be utilised to provide temporary wound cover. Strips may be alternated with autograft. As the

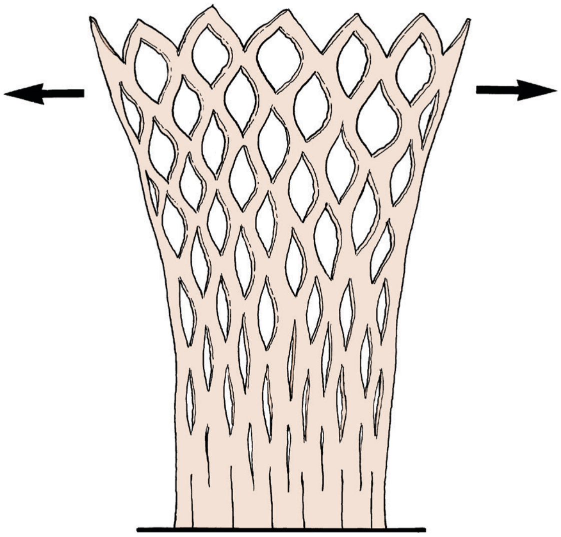

Figure 2.13 *Expansion of meshed skin.*

allograft is rejected, the patient's own epithelial cells grow out to replace them. All of these methods result in parts of the wound healing by secondary intention, with more resultant scarring and contracture.

Skin grafts may be stored for up to 2 weeks in a refrigerator at 4°C. Microbiological counts in the stored graft increase with time, and its use beyond 14 days is undesirable. After spreading the graft on tulle gras dressing, the raw surfaces should be folded together, the graft rolled up and lightly wrapped in a gauze swab wrung out in normal saline, and placed in a sterile container.

GRAFT APPLICATION AND FIXATION

The graft is placed over the recipient site and adjusted so that it conforms to any irregularity of the bed. Any portion of the graft not in contact with underlying tissue will die. The graft is tacked to the edges of the defect with a few well-spaced sutures, which can be left long and used to fix a 'tie-over' dressing (Figure 2.14). The graft can either be placed directly on the recipient site or first prepared on a sheet of paraffin gauze spread on a wooden board. The sheets of graft skin are laid with their superficial surface in contact with the paraffin gauze (see Figure 2.12d). If the gauze has been cut to the size of the recipient site – remembering that uneven contours will increase the size necessary – this can often make preparation easier. Any wrinkles or curled edges are attended to and the graft is trimmed as required. If several sheets of graft are necessary, the best configuration of the pieces can be planned. When no meshing device is available, and expansion is necessary, the graft can be meshed using a scalpel as it lies on the board as described above. Alternatively, just a few small slits can be cut to give the graft greater ability to conform. This will also allow exudate to escape and prevent it from lifting the graft off its new bed. The graft can then be transferred to its new site on the tulle gras dressing.

CARE OF GRAFTS: DRESSINGS OR EXPOSURE

Failure of the split-skin graft to 'take' completely is usually due to one, or a combination, of the following:

- a collection of serum or blood beneath the graft;
- infection; and/or
- dislodgement of the graft.

Exposure of skin grafts allows exudate or haematoma to be expressed in the first few hours and prevents shearing by a dressing. The graft is, however, exposed to other potential trauma, and patient cooperation and expert nursing are essential.

A dressing protects the graft from outside interference, but great care is needed over its application. Light pressure on the surface of the graft will reduce the chance of exudate lifting it from the underlying tissue. A crepe bandage over a layer of absorbent dressing is suitable for a flat or convex graft surface. However, if the surface of the graft is irregular or concave – for example, after the grafting of a wide excision of a malignant melanoma – a 'tie-over' dressing to fill the concavity is needed. This can be made from cotton wool soaked in sterile liquid paraffin and is held in place by tying the long ends of the sutures together over it (Figure 2.14). If the dressing slips or rotates, a shearing force may tear the graft from its position, so fixation of the final crepe bandage is essential, either by elastoplast or a light plaster. The dressings should be left undisturbed for 5–8 days unless pain, pyrexia or smell indicate the presence of infection.

Excision and grafting of burns

The extensive restoration of skin cover after major burns is rightly the domain of the specialist plastic surgeon. Every surgeon should be familiar with the immediate management of the burned patient before transfer to a specialist unit. Isolated general surgeons may have to continue the management themselves, and it must be remembered that tissue damage may extend deep to the skin and that the operative reconstruction is only a small but important part of the management of the severely burned patient.[12]

Split-skin grafts are used to cover the raw areas produced by full-thickness burns. The ideal management of a full-thickness burn is early excision of the dead skin, followed by immediate or delayed skin grafting. However, for a general surgeon managing a severely burned patient, with limited resources and no available blood for transfusion, it may still be better to opt for the traditional delay until the dead skin has separated spontaneously with the help of dressings. In

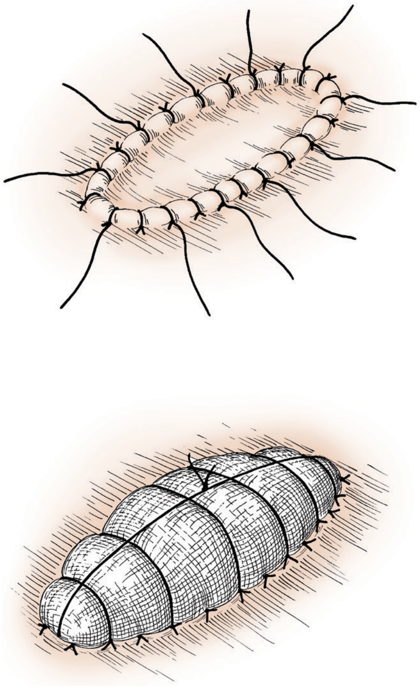

Figure 2.14 *Tie-over dressing.*

deep dermal burns, tangential excision (using a skin-grafting knife) down to the zone of punctate bleeding with immediate cover using thin split-skin grafts gives the best results.[13]

Full-thickness skin grafts (Wolfe grafts)

These grafts, which are composed of the full thickness of the skin, are unsuitable for use on granulating areas, but are ideal for resurfacing clean surgical wounds produced by excision of scars or tumours. They are particularly useful where texture, colour and durability are important. For this reason, they are widely used to correct facial deformities such as ectropion, scars and growths of the eyelids, nose and cheek, and also in the hand to correct deformities, burn contractures of the fingers, finger tip injuries and in the treatment of syndactyly.

The recipient site must have absolute haemostasis. An exact pattern of the defect is made in paper or foil, and a suitable donor site chosen that has skin of similar colour and texture. It should also be in an area where the resultant defect can be easily closed and a scar be inconspicuous. The postauricular sulcus (Figure 2.15) and the supraclavicular and infraclavicular regions are good donor sites. So, too, is the inframammary crease in the woman and the lateral groin in either sex, provided that care is taken not to transplant hairy skin. The pattern is used on the donor site to ensure that the correct size and shape is cut. The skin is dissected off the subcutaneous fat and any remaining fat trimmed from the undersurface of the graft before it is placed in the defect and secured in a similar fashion to a split-skin graft. The donor defect can usually be closed as a linear wound.

New technologies

A variety of new technologies are currently being explored to improve the quantity and quality of skin grafting. For example, Integra® is a dermal substitute with a silicone cover. Grafting this onto a clean wound 3–4 weeks prior to split-skin grafting may enhance the quality of the replaced skin. However, this is an expensive product with significant risks, and its use should be confined to specialist centres. Likewise, the use of cultured epithelial autografts as an adjunct to the resurfacing of extensive burns should only be considered in specialist centres in the context of research. Despite much research on the development and use of skin replacements, autologous skin grating continues to be the mainstay of burns treatment, as a satisfacory alternative remains elusive.

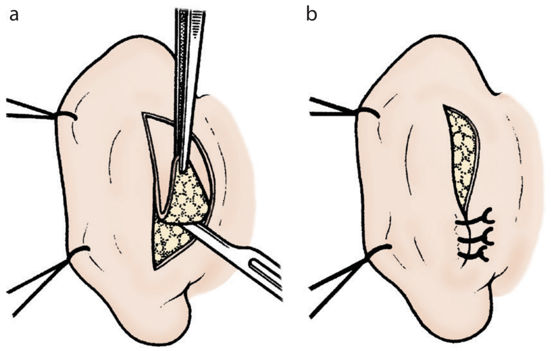

Figure 2.15 *A postauricular full-thickness skin graft. (a) The exact size and shape required is cut from the postauricular sulcus. (b) Linear closure of the defect is usually possible.*

TISSUE FLAPS

A flap differs from a graft in that it carries its own blood supply and is therefore not reliant on obtaining a blood supply from its bed. In certain circumstances, a flap may be mandatory as the bed of a defect is not suitable for skin grafting – as may be the case when there is exposed bone, tendon or joint. At other times, a flap may be chosen as a more aesthetic – or indeed a 'safer' – reconstruction. Great care must be taken in planning a flap, as in inexperienced hands the decision to use a flap may result in an escalation of the original problem.

The classification of flaps can be simplified by understanding that there are a number of methods of classification. Cars can be classified according to engine size, colour, body, shape or fuel requirements. Flaps can be classified according to congruity, configuration, components, circulation or conditioning (the 'five Cs'). A description of the vast array of flaps available is beyond the scope of this chapter. Flap surgery is mainly in the domain of the reconstructive specialist, but general surgeons should understand the principles on which they are based.[14] Surgeons should also be aware of the potential role of flaps in their subspecialty, and may wish to master some simple flap techniques that are relevant to their surgical practice. For example, a colorectal surgeon may wish to use a gluteal musculocutaneous rotation flap to close a perineal wound at the end of an abdominoperineal resection, and a fasciocutaneous rhomboid Limberg flap is commonly employed in the treatment of pilonidal disease (see Chapter 24).

Congruity

Flaps may be described as *local* when they lie immediately adjacent to the soft tissue defect. Alternatively, flaps may be regarded as *regional* when they are moved from an adjacent anatomical area or *distant* when they are moved from a remote anatomical site. A flap may be referred to as *pedicled* when it is moved with an intact tissue bridge to support it or *islanded* when there is no intact skin bridge, but an island of skin is moved under a bridge to fill a non-contiguous defect. Local skin flaps have the advantage that they provide skin of similar colour and texture to that which is lost.

Configuration

Local skin flaps can be moved to an adjacent area by one of three methods. They may be either advanced (Figure 2.16), rotated (Figure 2.17) or transposed (Figure 2.18). The amount of movement possible is dependent on the skin laxity. In general, *advancement flaps* give only limited mobility but are of great value in certain situations such as the finger tip. Their mobility may be enhanced by carefully 'islanding' them on a vascular pedicle. The geometry of *rotation flaps* requires a large flap to fill a relatively small defect. A rotation flap of buttock skin and muscle is widely used in the reconstruction of sacral pressure sores and a rotation flap of cheek skin is used in facial reconstruction. The mobility of the rotation can be enhanced by a back cut at the point furthest from the defect (Figure 2.17). *Transposition* of a flap results in the greatest degree of flexibility. However, flexibility is dependent on adequate mobilisation, which is in turn limited by blood supply. The rich blood supply of the face allows a flap with a relatively high length-to-breadth ratio to be raised. The donor site from flap transposition may be closed directly if there is sufficient laxity, but a skin graft is sometimes required.

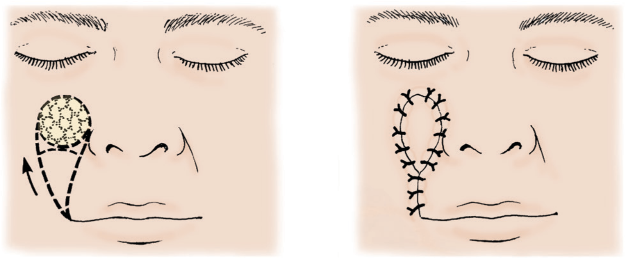

Figure 2.16 *V–Y advancement flap on a subcutaneous pedicle.*

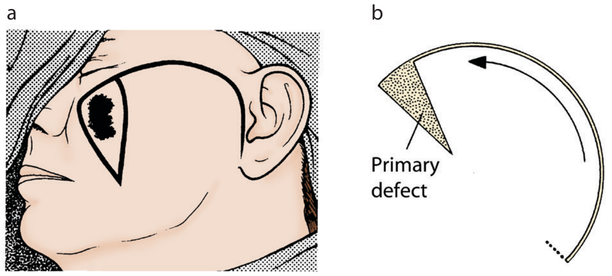

Figure 2.17 *A cheek rotation flap. (a) A large flap is necessary even when the defect is small. (b) A 'back cut' can be used to reduce tension.*

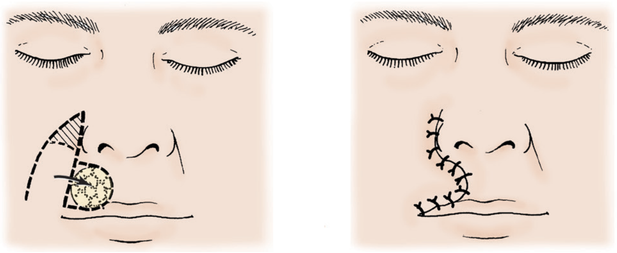

Figure 2.18 *Transposition flap from a nasolabial fold to a defect in the upper lip.*

Z-plasties are a manoeuvre in which two interdigitated triangular flaps are transposed to cover a defect. It is a particularly useful method of closure after the excision of linear contracted scars restricting movement in the neck, axilla and hand. From the extremities of the primary incision, incisions are made at an angle of 60 degrees so that the full incision resembles the letter 'Z' (Figure 2.19).

Components

Flaps may contain one or more tissue types. Local flaps of skin alone are commonly used to fill small cutaneous defects. Sometimes, a flap may consist purely of another anatomical component such as fascia, muscle, bone or even bowel. Flaps containing more than one variety of tissue are described in terms such as 'musculocutaneous' or 'fasciocutaneous'. The addition of muscle to a flap can provide the extra bulk required to fill a deep defect such as a sacral pressure sore. Even when extra bulk is not required, muscle or fascia within the pedicle and base of a flap may enhance its circulation.

Circulation

The raising of a flap deprives it of any circulation except that which arrives through its pedicle. Even in experienced hands, partial or complete flap necrosis may occur. Flaps may be regarded as having a random pattern circulation when they are raised without respect to the prevailing underlying circulation. In reality, because of incremental knowledge and experience, very few truly *random pattern flaps* are elevated. If they were, then theoretically the length-to-breadth ratio might be more limited in areas of poor vascularity (e.g. the lower leg) than in the richly supplied face. It has long been appreciated that flaps may be made longer and narrower when a vessel courses along their long axis. Examples of these *axial pattern flaps* include the groin flap (supplied by the superficial circumflex iliac artery) and the deltopectoral flap (supplied by perforating branches of the internal mammary artery). The long groin skin flap in particular was exploited for many years by plastic surgeons on the basis of experience, rather than anatomical knowledge. There is now a much greater understanding of cutaneous blood supply, to the extent that every body area has been mapped in detail.

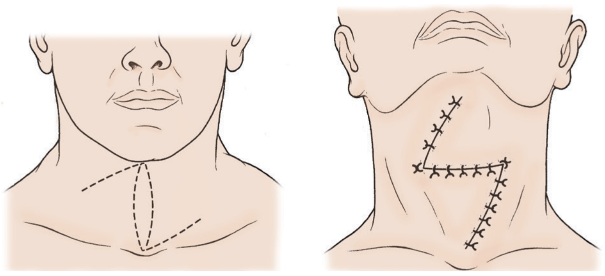

Figure 2.19 *Z-plasty to release a contracture on the neck.*

Skin may be supplied either by vessels running directly under the skin or by vessels that perforate through or between muscles. Thus, a large island of skin can be raised and moved to a distant site for reconstruction by utilising muscle as its pedicle. The latissimus dorsi flap, which is used in breast reconstruction, is an example and is described in Chapter 3, p. 42. The rectus abdominis flap, used to reconstruct sternal or perineal defects, is described in Chapter 13, p. 218. The pectoralis flap, used in head and neck reconstruction, is described in Chapter 11, p. 198, and the gastrocnemius flap, which is a standard flap technique for the reconstruction of defects in the upper third of the leg, is described in Chapter 4, p. 49.

The addition of anatomical components to a flap may enhance its circulation. For example, by incorporating deep fascia within a flap on the lower leg, a longer flap can be raised safely (Figure 2.21). This is partly so because vessels perforate in the intermuscular septi and then arborise upon the fascia. However, perhaps the greatest revolution in plastic surgery in recent years has been the greater understanding of the location of these 'perforating' vessels and their exploitation to raise 'perforator' flaps in a variety of anatomical locations.

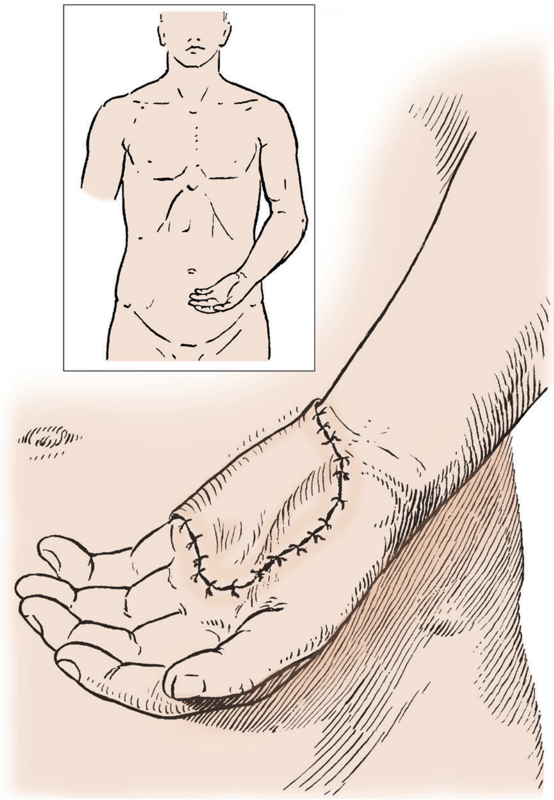

Figure 2.20 *Full-thickness skin cover is essential for the palm of the hand. A simple direct flap technique, which may still be of value when more sophisticated reconstruction is not available.*

Conditioning

The safety of a flap may be improved by enhancing its 'axiality', classically by cutting down either side of a flap as a prelude to raising it off the body, some days or weeks later. This is done to encourage the blood supply of the flap to run parallel along its long axis. Such a manoeuvre opens up 'choke' vessels, which connect adjacent areas of skin, and thus allows the capture of territories that would not, under most circumstances, be supplied by the vessel within the pedicle of the flap. This phenomenon is known as 'delay'. It should not be confused with the period of delay between inserting a flap into its recipient site and dividing its pedicle. In the simple flaps shown in Figures 2.20 to 2.23, the pedicle is only divided when the flap has established a blood supply from its new site – a process that normally takes around 3 weeks.

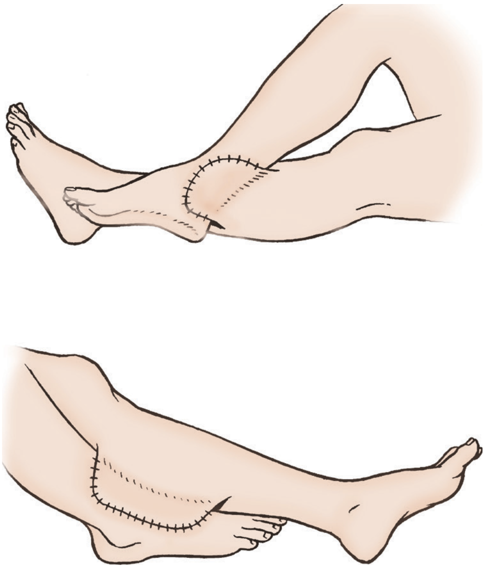

Figure 2.21 *Direct pedicle grafts from one leg to another. The disadvantages of several weeks of immobilisation were not insignificant, and these flaps have been virtually replaced by more advanced reconstructive procedures.*

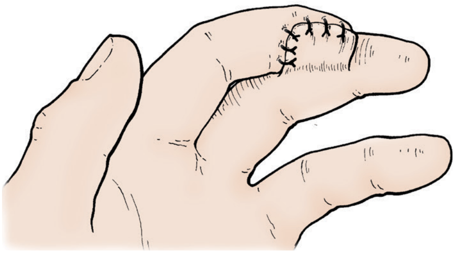

Figure 2.22 *Cross-finger flap. The flap has been raised from the dorsum of the middle phalanx of the middle finger to cover a defect on the tip of the index finger. (A split-skin graft will have adequate durability on the donor site.) After 3 weeks the pedicle of the flap is divided.*

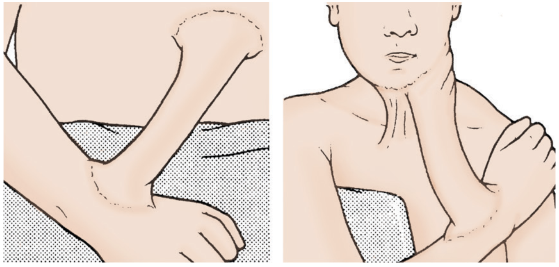

Figure 2.23 *An historical illustration. The long abdominal or groin skin flap was raised and its pedicle 'tubed' to protect the raw surfaces. The end of the flap was implanted into the wrist. Once safely established on the wrist, the pedicle was divided and carried on its new blood supply to cover a defect on the face or neck. More sophisticated reconstructive procedures have replaced this ingenious technique.*

Some of these older techniques are now used less frequently in specialist practice as the variety of reconstructive flaps has increased. Further reading is recommended for general surgeons with a particular interest.[14]

FREE TISSUE TRANSFER

Many of the composite flaps described above can be raised on their vascular pedicle, which is then divided to allow the tissue to be transposed as a free flap to almost any recipient site where there are suitable vessels to allow revascularisation of the free flap by microvascular anastomosis. This is a technique for the surgeon specialising in reconstructive surgery. One of many examples of free tissue transfer is the use of the radial forearm (Chinese) flap, which can be moved with the underlying radial artery and associated veins to a wide variety of locations for countless purposes.

TISSUE EXPANSION

This is a technique of gaining extra skin by the subcutaneous insertion of a silicone bag, which can be gradually expanded by injection of normal saline over a period of several weeks. The expanded skin may be used to provide a local flap, and has particular application in expanding the area of hairy skin available to cover large scalp defects. The technique is also used to provide a pocket for a breast implant.

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3

SURGERY OF THE BREAST AND AXILLA

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SURGICAL ANATOMY

The breast

The adult female breast lies predominantly on the deep fascia of pectoralis major and extends from the second to the sixth costal cartilages. Medially, it extends almost to the midline and laterally it continues as the *axillary tail* of the breast over the lateral edge of pectoralis major into the axilla. Superficially, the breast is separated from the skin by subcutaneous fat, except over the areola and the nipple. The breast substance consists of glandular tissue and surrounding fat. Alterations in hormonal levels cause structural and functional changes in the breast during pregnancy, lactation and, to a lesser extent, throughout the menstrual cycle.

The blood supply of the breast is mainly from branches of the internal thoracic (mammary) artery and the intercostal arteries, which pierce the intercostal muscles, and laterally from branches of the lateral thoracic artery. The lymphatic drainage is 85 per cent to the axillary lymph nodes and 15 per cent to the internal thoracic nodes (Figure 3.1).

The axilla

The axillary contents are the fat and lymph nodes bounded by the axillary walls. The medial wall is bounded by the chest wall covered by the serratus anterior muscle. The anterior wall of the axilla is formed by the pectoral muscles and the clavipectoral fascia. The posterior wall comprises the latissimus dorsi, teres major and subscapularis muscles. The axillary vessels and the brachial plexus lie along the narrow superolateral wall of the axilla. The axillary vein is the superolateral boundary of an axillary dissection. The axillary artery, with the brachial plexus around it, is superolateral to the vein and is thus safe and out of sight during an axillary dissection. Some branches of the plexus, however, will be encountered (Figure 3.2).

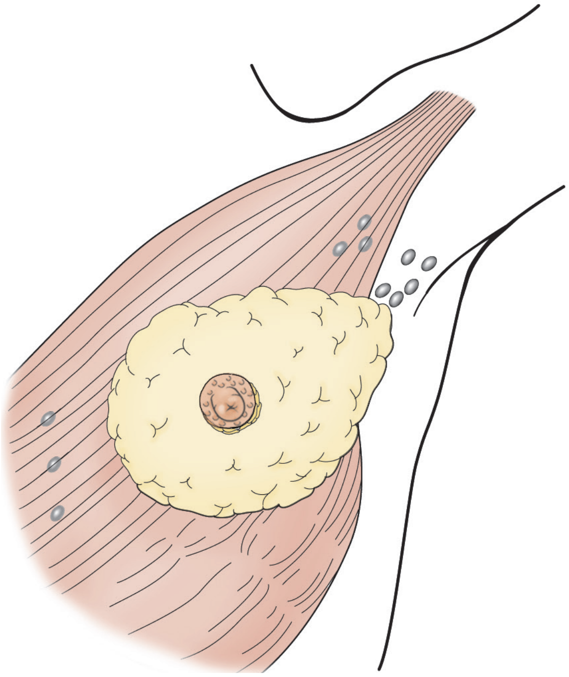

Figure 3.1 *Diagram of the left breast. The breast lies on the fascia of pectoralis major except for the axillary tail, which extends beyond the lateral edge of the muscle into the axilla. The lymphatic drainage is to the axillary and internal thoracic (mammary) nodes.*

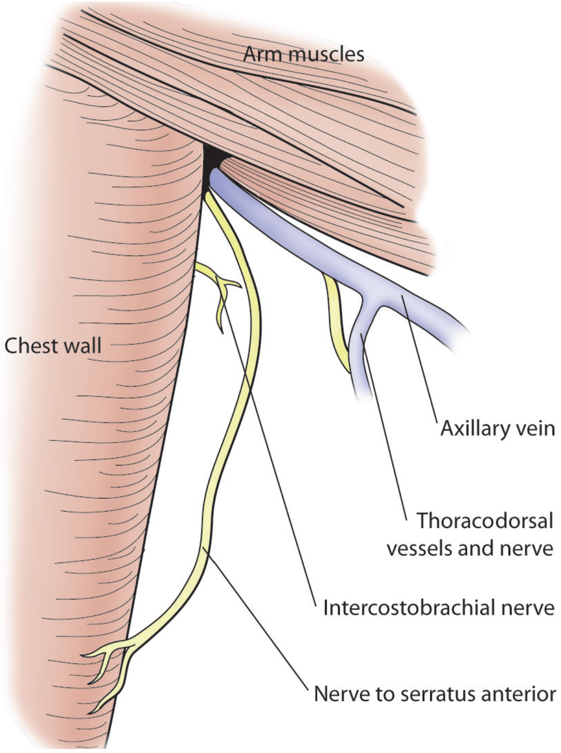

Figure 3.2 *The axillary vein is the superolateral limit of an axillary dissection. The thoracodorsal vessels and nerve are preserved on the posterior wall. The intercostobrachial nerve (shown divided) and the nerve to serratus anterior are encountered on the medial wall. The medial and lateral pectoral nerves, which cross the apex of the axilla, and the medial cutaneous nerve of the arm, running below and parallel to the vein, are not shown.*

The thoracodorsal nerve (the nerve to latissimus dorsi) and the thoracodorsal artery (a terminal branch of the subscapular artery) lie on the surface of the posterior wall and the nerve to serratus anterior on the medial wall; they should be identified and preserved. The nerves to the pectoral muscles cross the apex of the axilla and the medial cutaneous nerve of the arm runs parallel and inferomedial to the axillary vein. The intercostobrachial nerves cross the axilla from medial to lateral.

The axillary lymph nodes lie in the fat of the axilla and receive lymphatic drainage from the upper limb and the superficial tissue of the chest wall in addition to the breast. Lymphatic channels from the breast drain predominantly first to one or more sentinel nodes, usually low in the axilla, and then subsequently to the higher nodes and finally through the apex of the axilla to the supraclavicular nodes. The axillary nodes are arbitrarily divided into levels I, II and III dependent on their relationship to the pectoralis minor muscle (Figure 3.3). Level I nodes are lateral and below the muscle, level II nodes are behind it and level III nodes are above and medial.

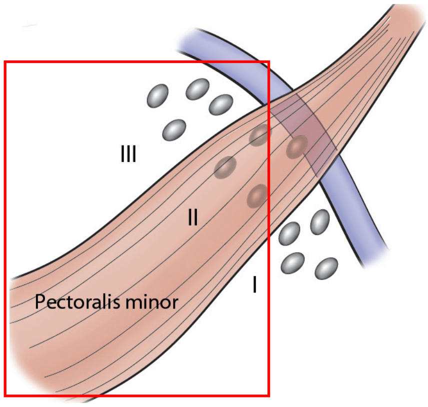

Figure 3.3 *Pectoralis minor is the landmark used to divide the lymph nodes into level I (below and lateral), level II (behind) and level III (above and medial) to the muscle.*

BREAST LUMP EXCISION

Breast lump excisions can be divided into local excisions and wide local excisions:

- *Local excision*: only includes the lump itself. This is a suitable technique for the removal of benign pathology.
- *Wide local excision (WLE)*: includes the lesion with a margin of macroscopically normal breast tissue. This has increasingly become the preferred surgical management in proven, and occasionally in suspected, early breast cancer. When an impalpable malignant lesion has to be excised, some method of marking the area must first be undertaken. Similar stereotactic and ultrasound methods can be used as for core biopsy and this can be done in the breast imaging suite under local anaesthesia prior to surgery. A wire is inserted percutaneously into the centre of the lesion. At excision the volume of tissue to be removed around the tip of the wire is judged by the extent of the lesion on preoperative imaging. After excision, the excised tissue should be X-rayed to check that the specimen removed incorporates the radiologically suspicious area.

A good cosmetic result should be sought. Circumferential incisions leave better scars than radial incisions and a scar can usually be hidden at the areolar edge or in the inframammary crease. Subcuticular skin sutures avoid any additional scarring. Incisions in the superomedial quadrant of the breast often result in hypertrophic scars in an area that is cosmetically sensitive – they should be avoided if possible. Invasion, or carcinoma in situ, beyond the primary tumour may extend to the margins of the excision and necessitate a later, more radical local excision or mastectomy. If this is anticipated, the incision should be within the ellipse of skin that might later be excised.

The skin scar is not the only cosmetic consideration. A large fibroadenoma displaces and compresses the surrounding breast tissue and local excision merely returns the breast to its original size. Careful haemostasis, followed by absorbable sutures in the breast tissue and a vacuum drain will eliminate the dead space and restore the contours of the breast. In contrast, a malignant tumour invades the breast tissue and a WLE will sacrifice a significant volume of breast tissue. If a poor aesthetic outcome is to be avoided, closure of the defect with direct suturing of the breast disc to eliminate dead space is advised. With good haemostasis a drain is rarely necessary.

During pregnancy the breast is significantly more vascular but otherwise poses no difficulties. Surgery on a lactating breast may be complicated by ongoing milk secretion at the operation site. A vacuum drain may compound the problem and establish a milk fistula. The situation may be better managed by repeat aspiration of the milk cyst as it recollects.

SIMPLE MASTECTOMY

An appreciation of the development of the breast from modified sweat glands deep to the nipple is fundamental to the concept of a mastectomy. The whole breast is excised with an overlying ellipse of skin that includes the nipple and areola. General anaesthesia is routine, but the operation can be undertaken with infiltration of large volumes of dilute local anaesthetic agent. The patient is placed supine with the arm abducted and supported on an arm board. In order to prevent shoulder capsular strain and nerve damage, abduction should be less than 90 degrees and the elbow should not be at a lower level than the shoulder.

The skin ellipse is marked. A low horizontal ellipse lies in the natural skin creases, but some obliquity affords better access to the axilla while keeping the medial end of the scar low and below the area of visible 'cleavage' (Figure 3.4a). The width of the ellipse is decided by issues of skin closure. Tension should be avoided, but excess skin may give an ugly folded scar and haematoma formation is also more likely.

The skin is incised as planned and the incisions deepened through the subcutaneous fat. The ideal plane of dissection is between the subcutaneous fat and the breast tissue, but it is not an easy plane to follow. Skin flaps that are too thick leave significant residual breast tissue *in situ*, while if the flaps are too thin the skin is in danger of losing its blood supply. First the upper flap and then the lower flap are raised until, at the edge of the breast, the plane comes down onto the deep fascia (Figure 3.4b). The breast is then dissected off the deep fascia from above downwards and multiple bleeding vessels secured (Figure 3.4c). If an area is encountered where the tumour has breached this plane, a disc of pectoralis fascia and muscle should be excised with the specimen. The lateral end of the dissection is the most difficult, as the plane between the axillary tail of the breast and the axillary fat is indistinct and the deep plane is also less obvious beyond the lateral border of pectoralis major. The skin flaps are traditionally closed over vacuum drainage. However, some surgeons have abandoned the routine use of drains by meticulous haemostasis and obliteration of the dead space with quilting sutures.

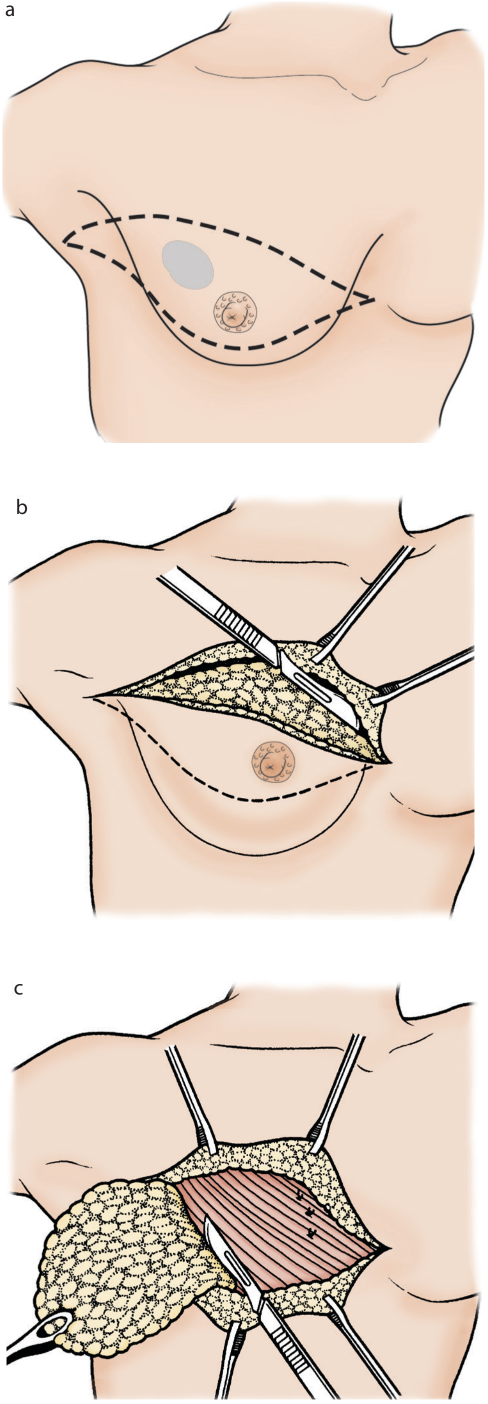

Figure 3.4 *A right simple mastectomy. (a) A slightly oblique ellipse keeps the medial end of the scar low and less conspicuous while also giving good access laterally to the axilla. (b) Dissection of the upper skin flap. The natural plane between subcutaneous fat and breast tissue is followed. (c) The breast is then dissected off the deep fascia from above downwards. When the lateral edge of pectoralis major is reached, the dissection of the axillary tail is continued into the axilla.*

LEVEL II AND LEVEL III AXILLARY CLEARANCE

A level II clearance removes the level I and II nodes and a level III clearance removes all nodes from levels I, II and III.

The patient is placed supine with the arm abducted in a similar position as for a simple mastectomy. It is important during the preparation of the skin with antiseptic that the arm is lifted forwards so that the skin over the posterior axillary wall is included, and a sterile drape is placed beneath it. Some surgeons then suspend the forearm, with the elbow flexed, above the patient in preference to placing it on an arm board. This produces less tension in pectoralis major, which can be retracted more easily.

The axilla is most often explored through a transverse lower axillary incision, which may be the lateral end of a mastectomy incision. It can also be explored through a vertical oblique incision at the lateral edge of the breast when this incision has been used for the breast surgery. When an axillary dissection is undertaken as part of a mastectomy, the breast and axillary contents are excised as a single specimen. The mastectomy dissection can be completed, except for the axillary tail, before entering the axilla. Some surgeons prefer to dissect up the upper flap only and then dissect the axilla, leaving the final freeing of the breast from the chest wall until later.

The lateral border of pectoralis major is defined and the fascia incised along its length (Figure 3.5a) to allow entry into the axilla. The axillary contents are retracted downwards and the fat is carefully incised over and parallel to the axillary vein until the vein is visible (Figure 3.5b). This is the superolateral border of the dissection. Tributaries entering the vein from the axillary fat are secured, divided and ligated. The clearing of the vein continues until the vessels lying on the muscles of the posterior wall of the axilla come into view. The most obvious are the thoracodorsal vessels. (This artery is the branch of the subscapular artery on which a latissimus dorsi flap depends.) The thoracodorsal nerve to latissimus dorsi emerges from behind the axillary vein just medial to the thoracodorsal vessels and then runs obliquely towards the vessels, forming an easily identifiable triangle on the posterior wall muscles (see Figure 3.2). Both the vessels and the nerve are preserved, but all of the fat and nodes should be dissected off them. The lateral border of latissimus dorsi is identified and marks the inferolateral limit of the dissection. The vein is then cleared up towards the apex of the axilla, behind pectoralis minor, which will have to be firmly retracted to obtain sufficient access to perform a level III clearance. The pectoral nerves and accompanying vessels will be encountered, crossing the upper axilla to the anterior axillary wall. The lateral pectoral nerve may have to be sacrificed. The medial pectoral nerve should be preserved if at all possible. Before completing the apical dissection it is easier to turn attention first to the medial wall and dissect the axillary contents off serratus anterior.

On the medial axillary wall, the large lateral branch of the 2nd intercostal nerve (the intercostobrachial nerve) is almost immediately encountered entering the axillary fat. Most surgeons sacrifice this nerve, although some try to dissect it out and preserve it. Further posteriorly, the nerve to serratus anterior tends to be lifted off the muscle with the axillary contents and needs to be carefully freed and allowed to drop back. Once this dissection joins the posterior wall dissection, the remaining apical fat and lymphatics are divided (Figure 3.5c).

Finally, the fat that still attaches the specimen to the skin incision infrolaterally is divided. Haemostasis should be meticulous, but lymphatic drainage will continue and vacuum drainage of the axilla is still favoured by most surgeons. This drain may have to remain *in situ* for 2 weeks.

SURGICAL MANAGEMENT OF BENIGN BREAST LUMPS

Improvements in diagnostic facilities, combined with a greater understanding of the normal cyclical changes within the breast, have reduced the number of benign breast lump excisions. Many nodular areas can be safely left *in situ*. Palpable cysts can be aspirated but a blood-stained aspirate or a residual lump after aspiration should raise the possibility of an underlying malignancy. A solid, discrete breast lump that is believed to be benign on all assessment criteria may be left, but some patients and surgeons prefer excision because of the small risk of a missed malignancy. Inevitably, surgeons who do not have access to reliable mammographic or cytological diagnostic facilities will have to excise more clinically benign lumps. Large fibroadenomas – described as 'giant fibroadenomas' when over 5 cm in diameter – occur in young women. The resultant breast asymetry and distortion will usually necessitate a local excision for cosmetic reasons. A phyllodes tumour is often initially excised as a suspected fibroadenoma that is growing fast. However, phyllodes tumours are found mainly in an older age group than fibroadenomas. Local recurrence after excision is common and a WLE of a phyllodes tumour with a margin of normal tissue is therefore recommended. Most are benign but the malignant (sarcomatous) potential varies. Rarely, blood-borne dissemination may occur, but lymph node metastases are not a feature.

Children in early puberty are sometimes referred to a surgeon with a tender lump deep to one nipple. This is a normal developing breast bud, and one breast frequently starts developing a few months ahead of the other. Excision is a disaster in a girl as she loses all potential breast tissue on that side. Later in puberty a girl may be concerned by enlargement of ectopic breast tissue, most commonly in the axilla. Reassurance may be all that is required but excision is indicated if it is unsightly. Boys also frequently present with tender developing breast buds at puberty and reassurance usually suffices. In some boys, however, development continues – often on one side and then the other – until there is a small breast protrusion, which causes considerable

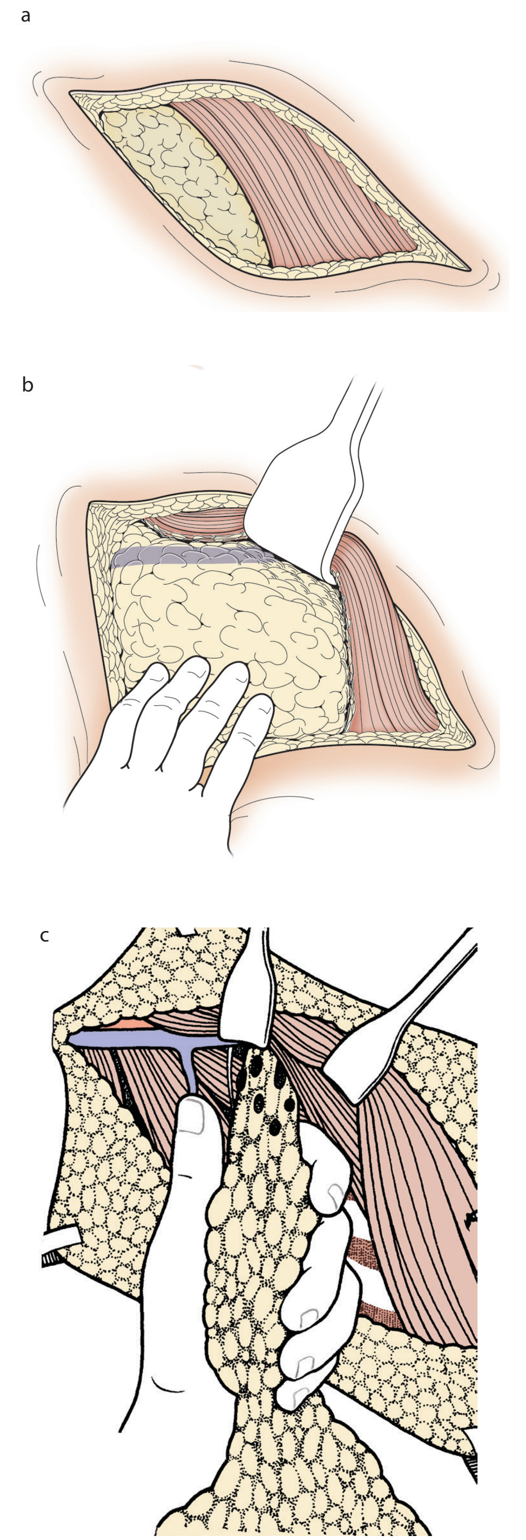

Figure 3.5 *A right axillary clearance. (a) The lateral border of pectoralis major is defined and the fascia incised along its length to gain access into the axilla. (b) The axillary contents are retracted downwards and the fat over the axillary vein is carefully incised until it can be identified. (c) The apical division of fat and lymphatics is easier after the medial and posterior wall dissection has been completed. (In this illustration the axillary dissection has been combined with a mastectomy, which has been completed first.)*

embarrassment. Regression usually occurs after a year or two, but embarrassment is often such that surgical excision is justified.

EXCISION OF GYNAECOMASTIA

An inframammary scar may be a continuing source of embarrassment and it is usually possible to excise even a broad-based breast through an inferior circumareolar incision. Dissection is commenced by lifting the areola and nipple from the underlying breast. A little breast tissue should be left attached to the undersurface of the nipple and areola to safeguard the blood supply and also to prevent a hollow in this region due to a lack of subcutaneous fat. The skin is then undermined circumferentially to the edge of the breast tissue, where the plane of dissection comes onto the pectoral fascia. The breast is then dissected off the pectoral fascia and delivered out through the wound. Access is restricted, and much of the dissection cannot be under direct vision; moreover, haemostasis is difficult until the whole breast has been excised. If difficulty is encountered, the breast can be transected and removed a quadrant at a time. A small extension at either end of the incision improves access but should be avoided, if possible, as it may result in a more obvious scar (Figure 3.6). Even if haemostasis is good, a vacuum drain is recommended as haematoma formation under the flaps is a common complication.

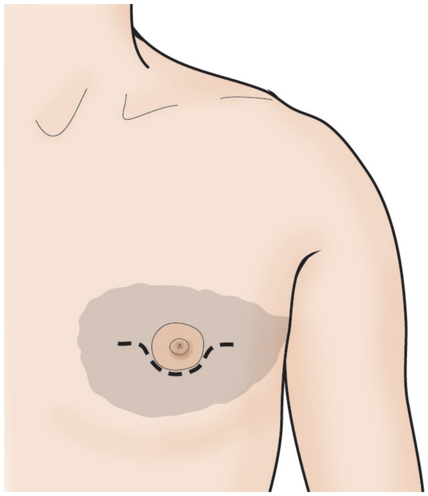

Figure 3.6 *Excision for gynaecomastia can involve the removal of breast tissue extending out over the whole shaded area. Lateral and medial extensions to the initial areolar edge incision may be necessary, but should be avoided if possible.*

SURGICAL MANAGEMENT OF BREAST INFECTIONS

Infection occurs most commonly – but not exclusively – in a lactating breast. In the early stage of inflammation an appropriate antibiotic may be all that is required. Once pus has formed drainage is required. If the abscess is already pointing with thinned overlying skin – often at the areolar edge – incision and drainage can be satisfactorily undertaken through a small incision under local anaesthesia. When antibiotics have been started too late the result is frequently a walled-off abscess, which fails to point. Instead, there is a deep indurated mass of inflamed breast tissue within which there may be multiloculated collections of pus. It is important that the surgeon remembers that an aggressive inflammatory breast cancer can mimic a breast infection. Deep pus in the breast is difficult to assess clinically, but can be confirmed by ultrasound. These deep abscesses were traditionally explored under general anaesthesia so that loculi could be broken down. A corrugated drain was left *in situ* to allow continuing drainage and to prevent premature skin closure (see Figure 4.7, p. 48). This surgery has now been replaced by ultrasound-guided aspiration, combined with aggressive antibiotic therapy. It has even been reported as an effective management strategy by surgeons without access to ultrasound.[1] Injection of local anaesthetic agent into the abscess cavity reduces pain during the procedure and also dilutes the pus, making aspiration easier. Aspiration can easily be repeated a few days later if more pus collects. There appears to be no contraindication to continuing breast feeding, and this should be encouraged, especially in areas of the world where it is crucial to the survival of the baby.

A recurrent or chronic abscess at the areolar edge is suggestive of an underlying *mammillary fistula* (Figure 3.7). Recurrence will continue until the fistula track has been eliminated. It can be deroofed, but better cosmesis will be achieved if the tract is excised via an approach similar to that shown in Figure 3.8. Recurrent infections deep to the nipple – often associated with nipple retraction and nipple discharge – are usually secondary to *periductal mastitis*. A major duct excision eradicates the source of the infection.

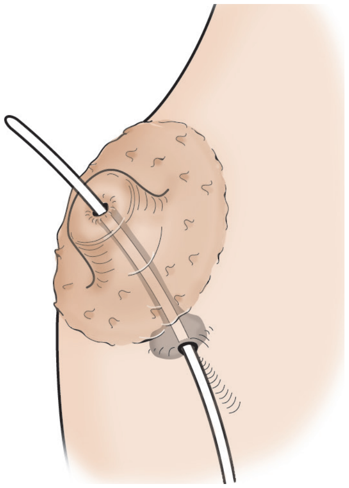

Figure 3.7 *The fine probe is in a mammillary fistula, which extends from a chronic areolar edge abscess to the opening of a duct onto the nipple.*

Neonatal swelling of breast tissue in either sex is a physiological response to maternal hormones. Occasionally, there is associated infection and a neonatal breast abscess. In a female child, care should be taken when draining this to cause minimal damage to the rudimentary breast bud.

SURGICAL MANAGEMENT OF NIPPLE DISCHARGE

Discharge from multiple ducts, which occurs in galactorrhoea, requires medical rather than surgical management. Discharge from multiple ducts can also occur in duct ectasia and in association with periductal mastitis. When symptoms cannot be controlled by other measures a formal major duct excision is indicated. Discharge from a single duct is also commonly secondary to a duct ectasia. However, if the discharge is blood stained, an intraduct papilloma or carcinoma should be suspected. A microdochectomy is performed for discharge from a single duct, either to alleviate distressing symptoms or to obtain tissue for histology to exclude malignancy.

MICRODOCHECTOMY

Local anaesthesia is satisfactory, but most patients prefer general anaesthesia for nipple and areolar surgery. The nipple is squeezed to identify the appropriate duct, into which a fine blunt probe is introduced. A sawn-off needle has the extra advantage of an eye, which can be used to secure the probe in place with a fine suture for the duration of the operation. The probe is then used to guide the surgeon in the removal of 3–5 cm of the appropriate duct. This can be approached by a radial incision in the areola or by an areolar edge incision, which may be cosmetically superior (Figure 3.8). After removal of the duct, which is sent for histology, the wound is closed with fine sutures.

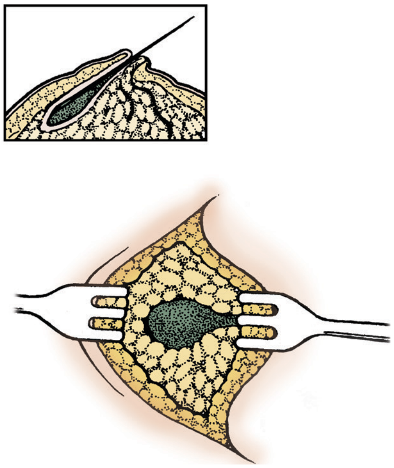

Figure 3.8 *A blunt probe or sawn-off needle is introduced into the discharging duct. Excision of this duct can be through either a radial areolar incision or an incision at the areolar edge.*

MAJOR DUCT EXCISION

Antibiotic cover is recommended. All the ducts under the nipple and areola are excised via an inferior circumareolar incision. A deep purse-string suture, to encourage nipple eversion before the skin suture is inserted, can improve the final cosmetic result.

SURGICAL MANAGEMENT OF BREAST CANCER

Historical overview of treatment modalities in breast cancer

Surgery of the breast has always been dominated by the management of breast cancer. Although further reading is essential to understand the current position[2,3], it is helpful to consider the issues within their historical context, as the surgical focus has evolved over time. Initially, surgeons were striving for cure through increasingly radical operations. This was followed by a search for the optimal place of surgery amongst the other effective treatment modalities. Now the focus has shifted to oncoplastic surgery, a combination of tumour excision and reconstruction.

The *Halsted radical mastectomy*[4], which included removal of the whole breast, the axillary contents and the pectoral muscles, was the original gold standard of surgical treatment. The *extended radical mastectomy* was a logical extension that achieved more radical lymphatic clearance by excision of the internal thoracic and supraclavicular nodes. However, morbidity was increased without significant advantages in survival or local control. The pectoralis major was excised in a radical mastectomy, as it was believed that the lymphatic drainage was mainly through the muscle; in addition, removal improved access to the axilla. Adequate access to the axilla is obtained by pectoral muscle retraction, however, and it is now known that there is no oncological benefit in removing the pectoral muscles. The radical surgical option is therefore now a *simple mastectomy* and an *axillary clearance,* in which pectoralis major and pectoralis minor are retained. The combined operation is sometimes described as the *Patey modified radical mastectomy*.

Radiotherapy is effective in the treatment of breast cancer and can be used as an alternative treatment to surgery, for both the breast and the axilla. Combining more conservative surgery with radiotherapy gives results comparable to radical surgery. This was shown by the early studies of McWhirter[5] and confirmed by many subsequent trials.

Conservative excision alone of a malignant breast lump often resulted in a recurrence within the breast. Similarly, performing a *simple total mastectomy* without treatment to the axilla was often followed by axillary recurrence. However, some women were cured without disfiguring surgery or the side-effects of radiotherapy and patients who can safely avoid unnecessarily radical therapy are now easier to identify.

The principle remains, however, that radical treatment includes treatment of the whole breast and axilla by one or other modality unless it can be shown that the individual patient does not require it. Safe avoidance of radical treatment of the breast and of axillary nodes in selected patients relies on the prediction of risk from the characteristics of the primary tumour and/or on the axillary staging operations described below.

Breast cancer responds both to *hormonal manipulation* and to *cytotoxic chemotherapy,* which are used in the control of metastatic disease and also as adjuvant and/or neoadjuvant therapy. Chemotherapy and hormone manipulation decisions are based on predictions of tumour behaviour. The Nottingham Prognostic Index is based on tumour size, histological grade and node status.[6] Patient age and menopausal status and the tumour receptor response to hormones are of additional value when predicting tumour behaviour.

The practice of optimal breast cancer surgery therefore requires cooperation between surgeon, radiologist, pathologist, radiotherapist and oncologist. Surgeons specialising in breast cancer have been shown to have better results than generalists.[7] This is primarily the result of the appropriate treatment modality being chosen for the individual patient, and is dependent on a high standard of histological, cytological and radiological diagnostic services and concensus decisions that are agreed at multidisciplinary meetings (MDTs). In the developed world the surgery of breast cancer has therefore been concentrated into specialist units. Surgeons practising in areas of the world where these diagnostic services are suboptimal, or where access to radiotherapy or chemotherapy is limited, may still have to rely more on the use of radical surgery.

Diagnostic and staging procedures

THE BREAST

The patient may have presented with a palpable breast mass or a suspicious area may have been detected by screening mammography; confirmation or exclusion of cancer must follow. Triple assessment is the combined evidence of the clinical, mammographic and cytological examinations and results in a confident preoperative diagnosis in almost all patients. If these assessments all predict malignancy, treatment can then be planned. When the results of the initial assessment are contradictory, more information may be gained by a core biopsy examined histologically. In many units, core biopsy is replacing fine needle aspiration cytology in the initial assessment. If the lesion is palpable, the surgeon can take the core biopsy with a specially designed needle passed through a small stab incision in the overlying skin, which has been infiltrated with local anaesthetic. Core biopsy of an impalpable lesion detected on imaging requires mammographic stereotactic localisation devices or guidance by ultrasound. Occasionally, doubt still remains and a WLE is usually the most appropriate next surgical step. This will not only give definitive histology but also is often sufficient surgical treatment of the primary breast tumour if malignancy is finally confirmed.

THE AXILLA

Axillary node involvement is of prognostic importance and affects decisions on systemic as well as local treatment. Radical treatment of the axilla by surgery or radiotherapy reduces symptomatic axillary recurrence. However, if the axillae of all patients are treated, about 60 per cent of patients have unnecessary axillary treatment as they have no nodal secondaries. Axillary clearance should be restricted to the node-positive axilla. Axillary staging is therefore important. Benign axillary nodal enlargement is common and clinical staging of the axilla has little to offer, as shown beautifully in the simple classic study by McNair and Dudley in 1954.[8] However, a palpable node that shows an abnormal signal on ultrasound imaging is likely to be replaced by tumour. Such a node can be sampled by fine needle aspiration or core biopsy; if malignancy is confirmed, this will avoid the need for an axillary staging operation.[9] The three operations that are commonly used to stage the axilla are a level I dissection, lymph node sampling, and sentinel node biopsy.

A concern over all lymph node staging procedures is that with more thorough histological examination of fewer nodes, there is a greater chance of detecting a small nodal metastasis, which will change the staging of the patient's cancer. A single node will have more sections examined by the histologist than each of 15 nodes from a full axillary dissection. The importance of micrometastasis in all tumours is still debated. Histocytochemistry techniques have added a further dimension to this debate, with the identification of isolated tumour cells in a lymph node. It is impossible to know whether such cells are merely awaiting death by the action of the immune defences or are in the process of establishing their own microcirculation to become a viable metastasis.

Axillary sampling

When this procedure is combined with a mastectomy or excision of a lateral tumour, access from the breast wound is often adequate, otherwise a small transverse incision will suffice. It only requires entry into the axillary fat to remove the most easily palpable nodes. These are commonly in the lower axilla, and a formal dissection of the axillary vein is seldom necessary.

Level I axillary dissection

A level I axillary dissection removes the lower axillary nodes. The operation follows the same principles of dissection as the level II operation described earlier (p. 34), but the dissection is only taken to the level of the lower border of pectoralis minor.

Sentinel node biopsy

This technique is similar to that used for malignant melanoma, as described in Chapter 2, p. 20. Basically, the first node in the axilla to receive lymphatic drainage from the breast is the relatively constant sentinel node(s), which can be identified by injection of either a radiotracer or a blue dye, or preferably both, into the breast. The aim is to remove any 'hot'or blue nodes for pathological evaluation. During this procedure any other palpable nodes are removed and included as part of the sentinel node biopsy specimen. Initial concerns about false-negative results have proved unfounded.[10]

SURGICAL TREATMENT OF BREAST CANCER

A patient may have a surgically operable tumour at presentation, a tumour which although operable could be considered locally advanced or a totally inoperable local situation. Separate from this the patient may have a high or low risk of metastatic disease or even proven metastatic disease at the time of presentation. In each situation the surgeon is aiming for a combination of the best local control with the optimum cosmetic result. However, the role of other treatments, the extent and the timing of surgery and even the advisability of any surgery at all may vary.

Operable breast cancer

Histologically clear margins on the excised specimen are important. This is usually possible with a WLE. As it is not necessary routinely to excise the skin overlying a breast cancer, skin incisions can be placed in more aesthetically acceptable positions, usually periareolar or inframammary, with subcutaneous tunnelling to the area of resection. Some surgeons accept a 1 mm microscopic clearance but others prefer 2 mm. Macroscopically, the surgeon is therefore attempting to keep 10 mm from the cancer. Unfortunately, WLE alone of large tumours in small breasts, or centrally placed tumours, will result in poor cosmetic results. Excisions of over 20 per cent of breast volume will almost always result in unacceptable deformity and the limit is around 10 per cent for inferior and medial tumours. Other strategies should be considered. A mastectomy, with the option of an immediate or late reconstruction, may be preferable. Alternatively, the WLE should be combined with some form of reconstructive procedure, involving either breast tissue displacement or tissue replacement (see below). There appears to be no oncological advantage in a mastectomy for most patients and the decisions revolve around the aesthetic issues of a satisfactory breast reconstruction. Residual breast or chest wall radiotherapy will more often be indicated after a WLE than after a mastectomy, but many mastectomy patients will still be advised to have radiotherapy to the chest wall and mastectomy scar. Conversely, there are some patients who have only had a WLE for very small tumours with wide margins who may be able safely to avoid radiotherapy to the residual breast tissue.[11]

SKIN-SPARING MASTECTOMY

This alternative to a simple total mastectomy for breast cancer preserves the breast skin envelope for an immediate reconstruction. A circumareolar incision is suitable for excision of a small breast but for a larger breast an additional radial inferior or lateral incision will increase access. Alternatively, an incision similar to that used for breast reduction can be used and the two skin flaps are elevated for access. The nipple and the areola are excised with the breast. The reconstructive alternatives are discussed below.

SUBCUTANEOUS MASTECTOMY

This is usually the preferred option for a prophylactic mastectomy for patients at high genetic risk of breast cancer. The breast is excised through a lateral or submammary incision, with preservation of all the breast skin, the nipple and the areola. The immediate reconstruction can give excellent cosmesis. After any mastectomy, residual breast tissue can be identified as there is no clear demarcation between the breast and subcutaneous fat. Thus, this operation does not totally eliminate the risk of death from breast cancer and the term 'risk reducing' is therefore preferable to 'prophylactic'.[12]

AXILLARY CLEARANCE

Patients in whom axillary staging has shown involved nodes require treatment of the axilla by either an axillary dissection or radiotherapy. Either treatment improves local control and may also marginally improve survival. A *level III clearance* (the removal of all three groups of axillary glands) is the most radical surgical treatment and is usually reserved for patients who have grossly involved nodes identified perioperatively. A level II dissection is the more routine clearance of an axilla. Some surgeons use axillary staging selectively, partly because a recent staging operation in the axilla can make an axillary clearance technically more difficult. These surgeons opt for a full axillary dissection in patients with a high predicted risk of nodal involvement and for those who have already had malignancy in an axillary node confirmed by core biopsy, but perform nodal sampling in those with a low risk. Axillary radiotherapy is an alternative treatment for the axilla when a staging operation shows nodal involvement.

A level II or level III axillary clearance may be performed in conjunction with a simple mastectomy or a WLE. It may also be undertaken as an isolated procedure when earlier axillary node sampling has shown the presence of tumour cells and surgery is felt to be preferable to radiotherapy. Level II or level III axillary clearance may very occasionally be indicated for obvious recurrent axillary disease in a patient who has already had radiotherapy, but should be avoided if at all possible. Not only do the radiotherapy changes make the surgery more difficult, but subsequent lymphoedema is almost inevitable.

Operable breast cancer with metastatic disease at presentation

Here the priority is control of the metastatic disease; often, systemic chemotherapy is the initial treatment. Surgery and radiotherapy to the breast and axilla are delayed and the advisability of surgery reassessed after the response to treatment. A similar approach is often recommended in a patient who, although there is no evidence of distant metastases at presentation, has an aggressive tumour with a high likelihood of as yet undetected metastatic disease. Again, the priority is control of any systemic micrometastases, and local surgery and radiotherapy may be delayed until after initial systemic treatment.

Locally advanced breast cancer

A tumour is considered locally advanced when there is extensive skin involvement with peau d'orange or ulceration, fixation to the chest wall or fixed axillary nodes. In these circumstances, neoadjuvant or primary systemic therapy with chemotherapy or endocrine manipulation, or both, can bring advanced locoregional disease under control. If the treatment converts the tumour to one that is operable, surgery of the breast and the axilla can then be undertaken as desribed above, followed by postoperative radiotherapy. If systemic therapy has not had a significant effect on the local disease situation, radiotherapy will usually give better control than surgery. Very occasionally there is still a place for a surgical salvage operation. It must be remembered, however, that if surgery is through tissue infiltrated by tumour and also damaged by radiotherapy, there is a risk of compounding the problem. These operations follow the standard pattern of wide excision of highly symptomatic malignant infiltration followed by reconstruction, often utilising a myocutaneous flap, onto healthy surrounding tissue.[13]

ONCOPLASTIC SURGERY AND BREAST RECONSTRUCTION

There is a growing appreciation that both oncological and aesthetic principles should be applied in breast cancer surgery. This oncoplastic approach may involve collaboration between breast surgeon and plastic surgeon, but increasingly breast surgeons are acquiring plastic surgical skills. Oncoplastic techniques can extend the range of breast conserving surgery and facilitate both wider resection margins and better post-surgery breast aesthetics.[14]

Safe tumour resection can be combined with breast restoration and/or partial reconstruction, followed by contralateral adjustment if necessary. Choice of technique depends mainly on the size and shape of the breast and the size and position of the tumour, in addition to the preference and experience of the surgeon. Counselling, in parallel with preoperative oncological and aesthetic planning, is critical to a favourable outcome, as patient expectations vary.

Similar aesthetic considerations apply when a mastectomy is indicated. Breast reconstruction can almost always be offered in the developed world and is increasingly requested. There are many factors to consider. Is radiotherapy likely to be indicated and is an immediate or a delayed reconstruction more appropriate? If immediate reconstruction is selected, should a skin-sparing approach be undertaken? Would a flap technique or an implant, or a combination of the two, be the most appropriate method? There are several possibilities and much revolves around whether the patient is to have postoperative radiotherapy. If no radiotherapy is advised, an immediate reconstruction after a skin-sparing mastectomy can give an excellent result, but radiotherapy can cause some deleterious cosmetic changes.[15] Delayed post-radiotherapy reconstruction after a simple mastectomy poses other challenges. The skin has lost elasticity and a tissue expander cannot create an adequate pocket. In addition, the scar frequently crosses what would be the dome of the reconstructed breast. Usually, in delayed reconstruction a myocutaneous pedicled flap, utilising either the latissimus dorsi or the rectus abdominus muscle, provides skin and bulk.

An approach called the immediate/later or sandwich technique can be used to retain breast skin after a skin-sparing mastectomy when radiotherapy is likely. A tissue expander is

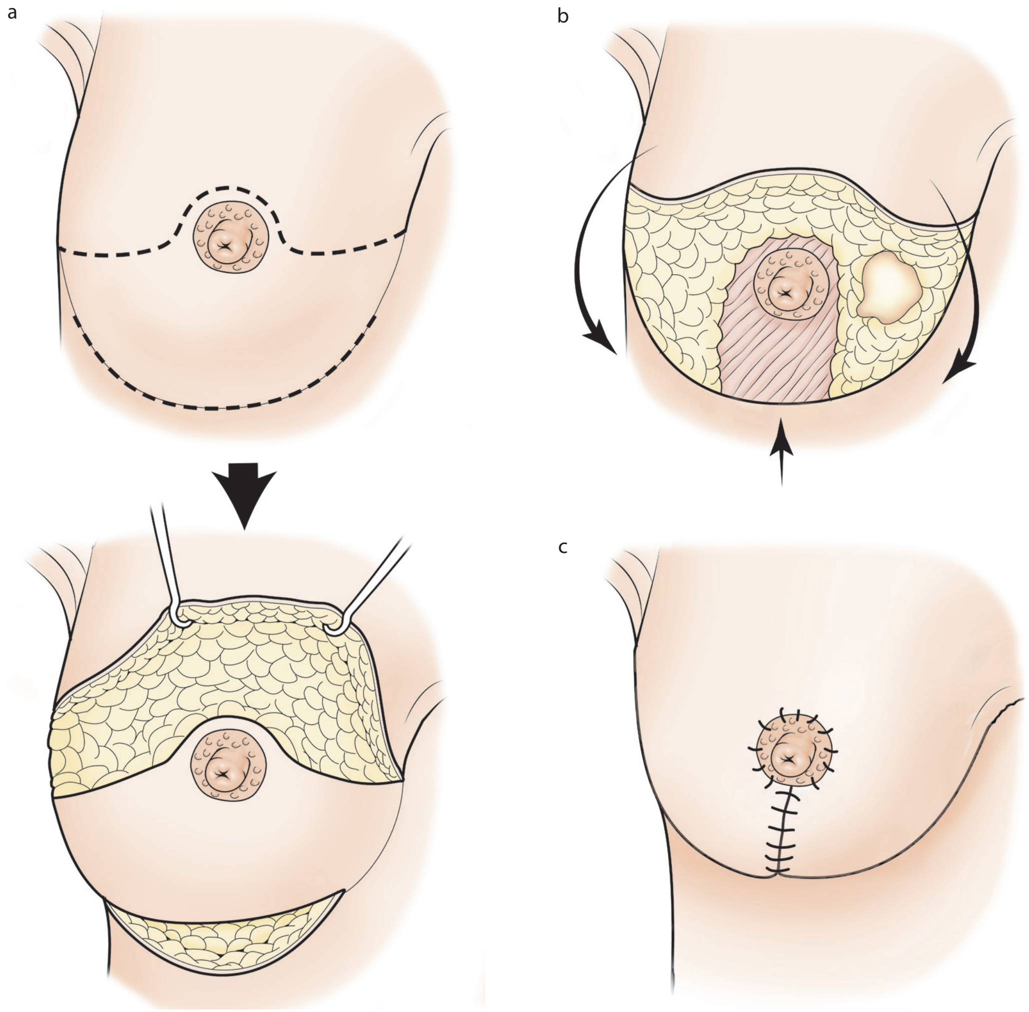

Figure 3.9 *Wise-pattern reduction mammoplasty. (a) Skin incisions, which can provide access to all parts of the breast by elevation of flaps. (b) All the exposed breast tissue can be excised. The epithelium is then shaved off the retained hatched area to form the pedicle on which nipple and areolar viability depends. The orientation of this pedicle can be modified according to the position of the tumour. (c) The breast disc has been reconstituted by glandular rotation and the skin trimmed and redraped. The nipple and areola have been lifted.*

employed, which is overexpanded during the period of radiotherapy. Subsequently, the space is definitively filled with a smaller permanent prosthesis or a myocutaneous flap.

Free flaps require specialist microvascular skills, which are unlikely to be available outside the largest specialist breast or plastic units. When a flap does not contain sufficient bulk to replace the excised breast, the flap can be combined with a silicone implant or a reduction mammoplasty can be performed on the contralateral breast to achieve symmetry.

Volume displacement/reduction

Volume displacement involves parenchymal redistribution and, sometimes, skin and subcutaneous tissue redistribution after resection of breast cancer.[14] This can be as simple as breast disc mobilisation and primary suture after a segmental resection. In this case, minimal skin mobilisation is necessary and usually no contralateral breast reduction. For larger resections in larger ptotic breasts, a Wise-pattern reduction with wide elevation of skin flaps and a central mound approach to retain nipple and areolar viability enables resections in all areas of the breast (Figure 3.9). Alternatively, a tumour-adapted mastopexy can be orientated to the breast resection (Figure 3.10). Contralateral symmetry surgery is usually necessary following these procedures. For central resection involving loss of the nipple/areolar complex, a Grisotti flap of skin on a dermo/glandular pedicle is a simple way of restoring the central breast area (Figure 3.11).

To facilitate postoperative radiotherapy, marking the tumour cavity with metallic clips prior to repair of the breast disc will be necessary since the skin incisions give little clue to the site of the tumour bed when these techniques are employed.

Volume replacement

Larger resections are possible, without the need for contralateral symmetry surgery, if the original breast volume and shape can be restored by volume replacement. Implants are unsuitable since radiotherapy will usually be advised.

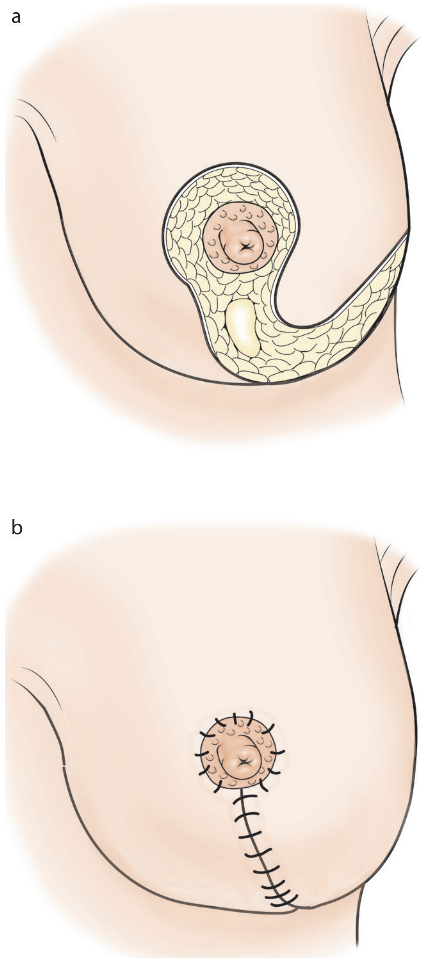

Figure 3.10 *The tumour-adapted mastopexy, orientated to the position of the tumour, combines tumour resection with a breast reduction and lift.*

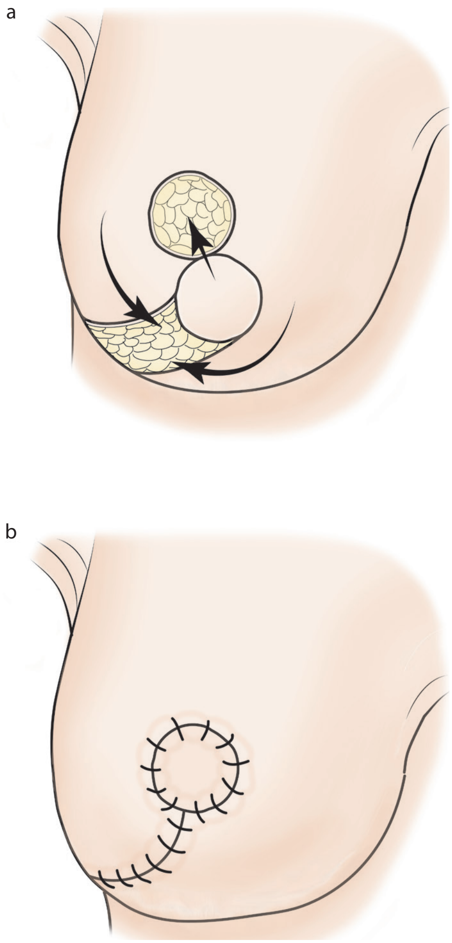

Figure 3.11 *Grisotti flap. (a) A wide local incision of a central lesion has included the nipple and areola and a skin paddle based on a dermoglandular pedicle has been prepared. (b) Advancement of the flap restores skin and breast tissue into the central defect.*

Autologous tissue replacement employs local flaps with axial blood supply, such as the lateral thoracic adipocutaneous flap or a myocutaneous or myosubcutaneous flap, usually the latissimus dorsi flap or ‘mini’ flap.

LATISSIMUS DORSI MINI FLAP

This myosubcutaneous flap of latissimus dorsi is used for volume replacement in the lateral half of the breast. It can be undertaken at the same time as the initial surgery, but some surgeons delay for a few days to have confirmatory histology of the clearance margins before proceeding.[16] The WLE is undertaken with careful preservation of the overlying skin. The flap is harvested from within the axilla at the same time as any axillary surgery, such as a sentinel node biopsy or a full axillary dissection. The vascular pedicle (thoracodorsal neurovascular bundle) is carefully isolated and the latissimus dorsi muscle is dissected free of the underlying serratus anterior muscle and chest wall. The subcutaneous plane is developed to allow isolation of an area of muscle and fat large enough to more than fill the breast defect, as shrinkage of the tissue in the flap occurs over time. Division of the latissimus dorsi tendon prevents later retraction of the flap, which is then rotated into the defect and fixed to the cavity walls.[17]

LATISSIMUS DORSI MUSCULOCUTANEOUS FLAP

This is the most widely used method of breast reconstruction following mastectomy. After completion of the mastectomy and any axillary clearance, the patient is turned on her side and a suitably sized ellipse of skin marked overlying the latissimus dorsi muscle. The long axis of the skin ellipse, or ‘paddle’, can be made in a variety of directions. It may be made transverse to hide the scar under the bra strap, or it may be made perpendicular to the muscle fibres, as this is the line of maximum skin laxity. The paddle is placed sufficiently posteriorly and inferiorly to afford adequate length to the flap (Figure 3.12a). The skin is incised, leaving the ellipse attached to the underlying latissimus muscle. Skin and fascia are dissected off the muscle proximal and distal to the skin ellipse to expose the boundaries of the muscle. Deep dissection commences at the anterior border and proceeds medially and inferiorly. The inferior extent of the muscle is attached to ribs and intermingles with the origin of the external oblique muscle, from which it can be difficult to differentiate. The medial attachment to the thoracodorsal fascia is divided carefully, continuing cranially where it is deep to the inferior origin of the trapezius. The upper border is defined and dissected towards the angle of the scapula and superolaterally to the latissimus dorsi tendon. Further careful deep dissection identifies the thoracodorsal vessels, on which the flap viability depends, and the branch to serratus anterior, which is also preserved if possible. Dissection is carried along the flap pedicle and tendon of insertion until the flap can be rotated and passed subcutaneously around the chest wall to fill the breast defect (Figure 3.12b). Occasionally, it may be necessary to divide the tendon to allow adequate flap positioning. The neurovascular bundle is particularly at risk during tendon division and must be identified accurately and protected. The donor site is closed over suction drains and the patient returned to the supine position. The latissimus dorsi muscle forms all or part of the tissue replacement for the excised breast and is sutured to the underlying pectoral fascia. In an immediate breast reconstruction, with skin sparing via a circumareolar incision, the skin ellipse is de-epithelialised except for the area required for areolar replacement. In a delayed reconstruction the skin ellipse is sutured to the upper and lower mastectomy flaps. A silicone implant is often required deep to the flap to provide additional volume.

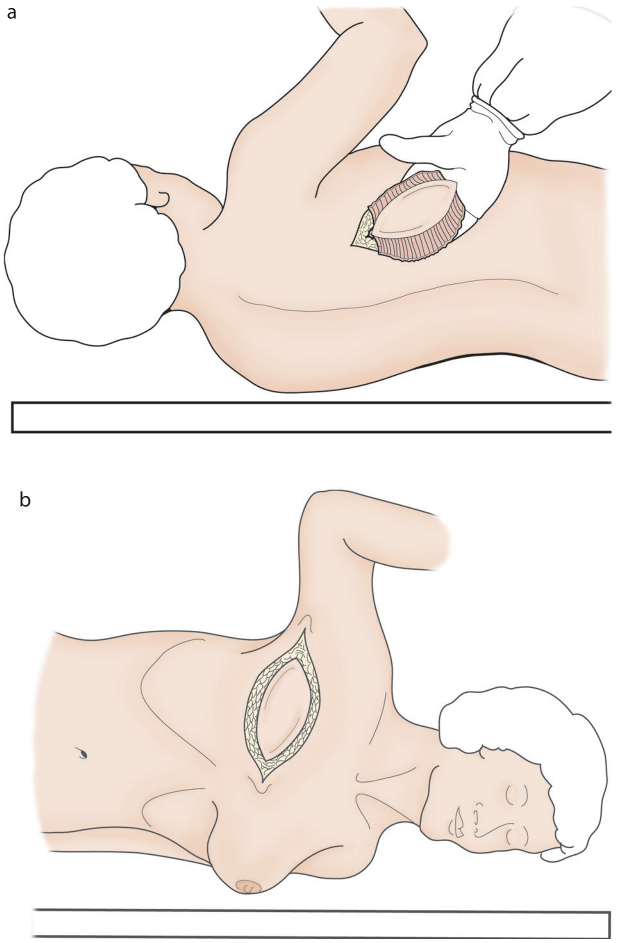

Figure 3.12 *A right latissimus dorsi reconstruction. (a) An ellipse of skin just below the scapula is raised with its underlying portion of latissimus dorsi. The posterior origin of these muscle fibres is divided to create a compound flap on a pivot point close to the origin of the subscapular artery. (b) The myocutaneous flap is rotated and tunnelled subcutaneously into the mastectomy wound defect. The donor site is closed as a linear scar.*

TRANSVERSE RECTUS ABDOMINIS MUSCULOCUTANEOUS FLAP

The transverse rectus abdominis musculocutaneous (TRAM) flap is preferred by some surgeons to a latissimus dorsi flap. Greater muscle bulk can be obtained and the transverse lower abdominal skin paddle not only provides skin of a better match, but its removal may also improve the appearance of the stretched lower abdominal skin. The pedicled TRAM flap is brought up by mobilisation of the whole of the opposite rectus muscle on the somewhat perilous blood supply of the internal thoracic artery. A free TRAM flap, or a free deep inferior epigastric artery perforator (DIEP) flap, based on the inferior epigastric artery, is increasingly employed where microsurgical skills are available (see Chapters 2 and 13). A free TRAM flap only sacrifices a small portion of rectus abdominis with reduced donor site morbidity. The free DIEP flap contains no muscle.

SILICONE IMPLANTS

Implants are used mainly as additional bulk where a latissimus dorsi flap alone is insufficient to achieve symmetry, but they can also replace the whole breast after a skin-sparing or subcutaneous mastectomy. The implant is placed, when possible, partly deep to the pectoralis major muscle. Silicone implants are also used for the complete or partial failure of breast development and are the commonest form of breast augmentation in the field of cosmetic surgery.

Late complications include implant rupture and silicone leakage. Capsular contracture around an implant is not uncommon, with a worsening cosmetic result. This is a particular problem when the implant has been inserted prior to radiotherapy.

Areolar and nipple reconstruction

Many patients are satisfied with the breast mound reconstruction and opt for no further surgery. Prosthetic adhesive areola/nipple complexes are available and if tailor made by a cast taken from the other breast, can be very satisfactory. Alternatively, a nipple can be fashioned by a local skin flap or by a nipple-sharing graft from the other breast. Tattooing can then reproduce the colour of the contralateral areola.

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4

SOFT TISSUE SURGERY: MUSCLES, TENDONS, LIGAMENTS AND NERVES

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Although it is the orthopaedic surgeon who operates most frequently on these tissues, an understanding of the surgical principles is still essential to the general surgeon. Trauma and infection occur in the soft tissue of both the trunk and the limbs, and there is significant overlap between surgical specialties. This chapter may also be of some value to the general surgeon who is unable to obtain specialist help and has to operate in unfamiliar 'orthopaedic territory'. However, the true surgical generalist may find that a large proportion of his or her surgical practice is in this mainly orthopaedic area, and will wish to supplement this chapter with further operative texts.[1]

SURGERY OF SOFT TISSUE TRAUMA

The severity of damage both to muscle and to other soft tissue is often underestimated, as attention is focused on the more obvious skin wound or the fractured bone visible on X-ray. For example, a high-velocity bullet that has passed through the upper calf may have inflicted small entry and exit wounds and a tibial fracture. The fracture appears to be the most significant injury, and initially it may not be appreciated that almost the entire calf musculature is necrotic, that there is nerve and arterial damage and that the viability of the distal limb is under threat. Soft tissue trauma inflicts three separate insults: direct tissue injury, tissue ischaemia and the introduction of infection.

DIRECT TRAUMATIC DAMAGE

A knowledge of the mode of injury is a useful predictor of the likely damage. A stab wound with a sharp knife causes minimal damage except to the tissue that is severed. Blunt injury may produce an area of damaged or even non-viable tissue, with little overlying skin damage. A high-velocity missile imparts kinetic energy to the surrounding tissue and a temporary cavity forms with traction forces on the tissue and disruption of small vessels. The cavity sucks in contaminants and then collapses. The final result is extensive contaminated tissue death surrounding an apparently small-calibre track (Figure 4.1).

DAMAGE TO THE BLOOD SUPPLY

An injury may sever a major vessel. However, the damage to an artery may be more subtle with only a partial tear in which the distal circulation is initially preserved but deteriorates later (see Chapter 6). Injury to a major vessel in the vicinity of a penetrating wound must always be suspected, especially if there is evidence of nerve damage. More commonly, the swelling of injured soft tissue within a closed fascial compartment (*compartment syndrome*) impedes perfusion as pressure rises.

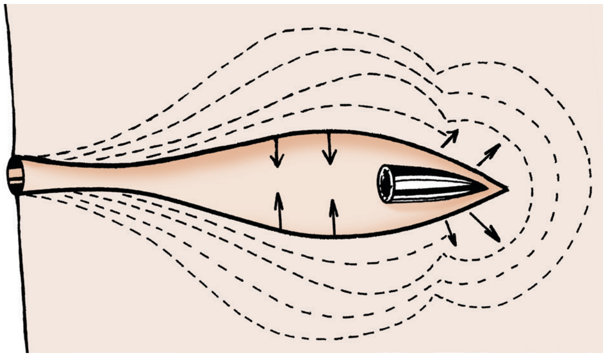


Figure 4.1 *A high-velocity missile causes extensive damage to the tissue around the track.*

INFECTION

Any trauma that breaches the skin or mucosa can introduce infection. However, a sharp injury inflicted with a non-sterile knife seldom results in significant infection. In contrast, penetrating injuries with blunt objects are associated with a high risk of infection, as virulent organisms may be carried into tissue that has also been contused or rendered ischaemic by the injury. Infection of damaged tissue leads to further tissue necrosis. Gross contamination, with soil or clothing carried into necrotic tissue, almost inevitably results in severe limb- and life-threatening infection as the necrotic debris and haematoma are an ideal culture medium.

Surgical removal of dead tissue and contaminants

The nature of the injury gives a good preoperative indication of the likelihood of extensive soft tissue necrosis or gross contamination. All dead tissue must be excised and all vegetable debris removed, or severe complications are inevitable. A small skin wound may have to be extensively enlarged in order to achieve adequate access. Any tissue of doubtful viability can be left for a second inspection after 24–48 hours (see Delayed repair, below). Metallic foreign bodies, such as bullets, shotgun pellets and pieces of shrapnel, may remain quiescent for a lifetime and do not always need to be removed; a surgeon is always at risk of causing more damage than the original weapon.[2] However, it must be remembered that clothing and other contaminants, invisible on X-ray, may also be in the wound and that a lead-containing foreign body may cause lead poisoning.

Surgical preservation of tissue perfusion

If a major vessel has been severed and there is distal ischaemia, arterial repair is of the utmost urgency if amputation is to be avoided (see Chapter 6).

Oedema and *swelling* occur with any injury and are more marked in blunt injuries with significant tissue contusion. Elevation of the affected part (Figure 4.2), which reduces oedema, remains a mainstay of management in most situations. *Compartment syndrome* is the result of bleeding or swelling within a restricted space leading to excessive interstitial pressure. The critical pressure is that which impairs venous return from the compartment, and is approximately 30 mmHg below the diastolic arterial pressure. It can be caused not only by trauma but also by other insults, including even severe unaccustomed exercise. The muscles of an acutely ischaemic limb that has been revascularised will also later swell, and the resultant compartment syndrome can lead to the loss of a successfully revascularised limb. Pain that is out of proportion to the injury and increased by passive stretching of the affected muscles is the cardinal sign. Urgent decompression by fasciotomy, before irreversible ischaemic muscle damage occurs, is vital if a functional limb is to be salvaged. Minor compartment syndromes may settle with elevation and rest, and the decision whether to operate is sometimes difficult. More is lost, however, by failure to act than by an unnecessary operation.

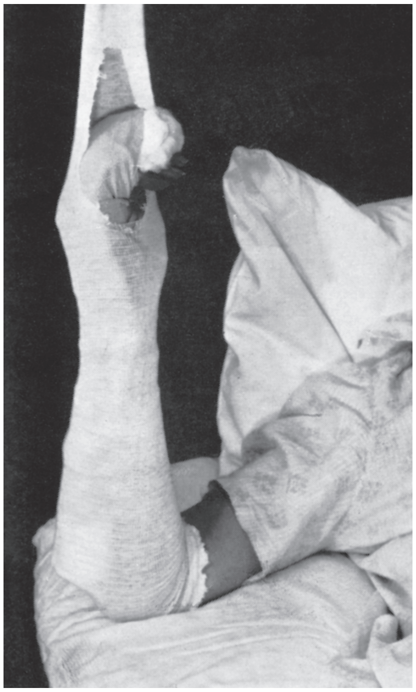


Figure 4.2 *Elevation of an injured hand. The photograph was taken by Eric Farquharson using a member of his family as the model.*

FASCIOTOMY

Fasciotomy is the treatment of any significant compartment syndrome.[3] The fascia must be opened along the length of the muscle belly. This can be achieved by a subcutaneous fasciotomy, but it is easier, and safer, to incise the whole length of overlying skin. This will not only release any associated skin constriction but will allow inspection of the ischaemic muscle, which should 'pink up' within a few minutes if decompression is timely. Viable muscle will contract if gently 'pinched' with forceps, and devitalised muscle becomes pale pink and non-contractile. Closure by secondary suture is appropriate when the swelling subsides after a few days, but skin grafts may be needed. Occasionally, only one fascial compartment is at risk. More often all compartments need decompression.

In the *leg*, an incision behind the medial border of the tibia can be used to decompress the deep and superficial posterior compartments. A second incision 4 cm lateral to the tibia is required if decompression of the anterior and peroneal compartments is also indicated (Figure 4.3). Alternatively, if flaps are raised at the level of the deep fascia, a single lateral incision will provide access to all four compartments (Figure 4.4). When the peroneal compartment needs to be decompressed, the level of the fibular head should be identified and used as a landmark to avoid damage to the common peroneal nerve as it winds around the neck of the fibula. Although the leg is the commonest site for a compartment syndrome, it can also occur in the thigh, foot and upper limb, but decompression is seldom required.

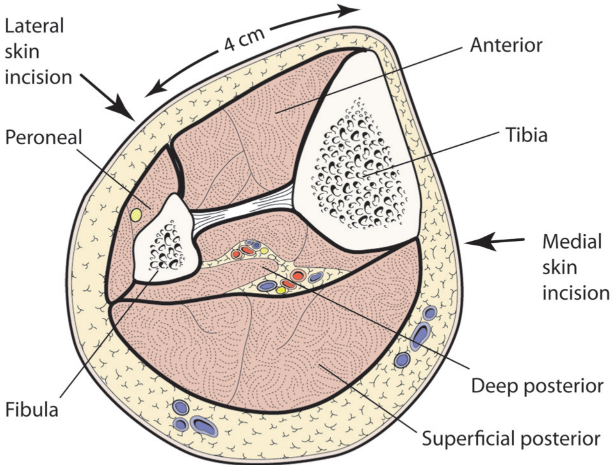


Figure 4.3 *An incision behind the medial border of the tibia affords access to both posterior compartments of the calf. A second incision 4 cm lateral to the anterior border of the tibia is required for access to the anterior and peroneal compartments.*

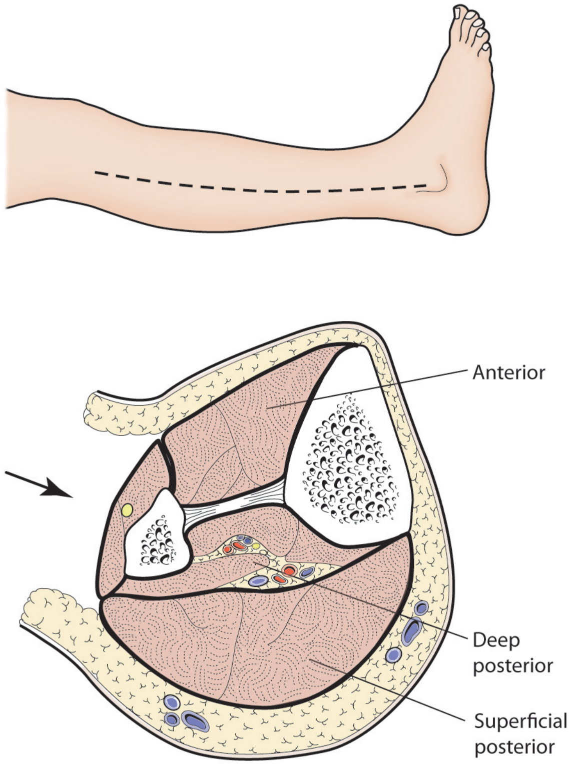


Figure 4.4 *A single incision over the fibula with elevation of flaps allows access to all four compartments.*

Surgical repair of soft tissue injury

Primary suturing

Primary suturing of deep tissues and skin is suitable in clean wounds. It may also be appropriate management, with antibiotic cover, in selected contaminated wounds, but thorough wound toilet combined with excision of devitalised tissue is essential prior to closure.

Delayed repair

This is always the safer option. Before the advent of antibiotics it was considered mandatory for any potentially contaminated wound and for any wound in which wound toilet had been delayed. Antibiotics have merely moved the dividing line between wounds that can be treated by primary closure and those that cannot. If there is established infection and tissue of doubtful viability has been left *in situ*, then primary closure is still potentially disastrous. The wound is cleaned, dead tissue excised and the cavity lightly packed with saline-soaked gauze. Forty-eight hours later the wound is re-explored. If there is no infection and the tissue of doubtful viability is now healthy, the deep tissues can be repaired and the wound closed. If, however, there is now further necrosis and infection, the wound is again debrided and left open.

MUSCLE REPAIR

Longitudinal incisions of muscle do not require sutures. A loose suture is at best harmless, while a tighter suture strangulates muscle fibres. However, the overlying fascia may be sutured if there is no significant muscle swelling and its closure prevents a potential *muscle hernia*. Closed trauma in the form of a severe force can cause a transverse mucle belly tear and a knife wound can inflict a transverse laceration. Divided muscle fibres retract and may be noticeable as a 'tumour' proximal to the injury when the muscle contracts. The divided fibres atrophy and there is compensatory hypertrophy of the remaining intact fibres. A surgical repair is therefore usually only indicated for a laceration or tear that has divided a significant proportion of the muscle. When the fascia has also been divided, sutures to appose the fascia may be sufficient to hold the muscle fibres in apposition. It is on this principle that the closure of a Kocher subcostal incision is based (see Chapter 13). If a muscle belly repair is indicated, a figure-of-eight suture will be the least likely to cut

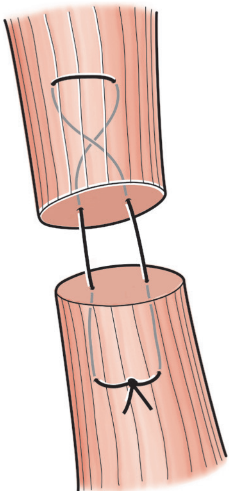


Figure 4.5 *A figure-of-eight suture is less likely to cut through muscle.*

out (Figure 4.5). An absorbable suture that loses its tensile strength relatively slowly (e.g. Vicryl™ or PDS™) is suitable. Splintage for about 6 weeks after repair is recommended, but there will be a risk of adhesions and stiffness if splintage is prolonged.

RECONSTRUCTION AND TISSUE COVER

This may be best delayed until both the patient and the wound have entered a healing phase, but bone or major vessels exposed by skin and muscle loss may require urgent tissue cover, which can be provided by muscle flaps (see below). Any early reconstruction is dependent on a clean wound with a good blood supply.

INFECTION OF MUSCLE

Pyogenic muscle infection

This most commonly occurs secondary to penetrating trauma, even if this is only in the form of a minor puncture wound. Occasionally, pus tracks into a muscle from an adjacent deep abscess. For example, a psoas abscess, although pointing in the groin, is usually secondary to a retroperitoneal infection, which may be vertebral, colonic or renal (Figure 4.6). In malnourished or immunocompromised individuals, a primary pyomyositis of large muscles may occur, and this is a common condition in some tropical countries. Whatever the aetiology, adequate drainage of pus and excision of any necrotic tissue are indicated. A drain should be secured into the depths of the abscess to prevent premature closure of the track (Figure 4.7).

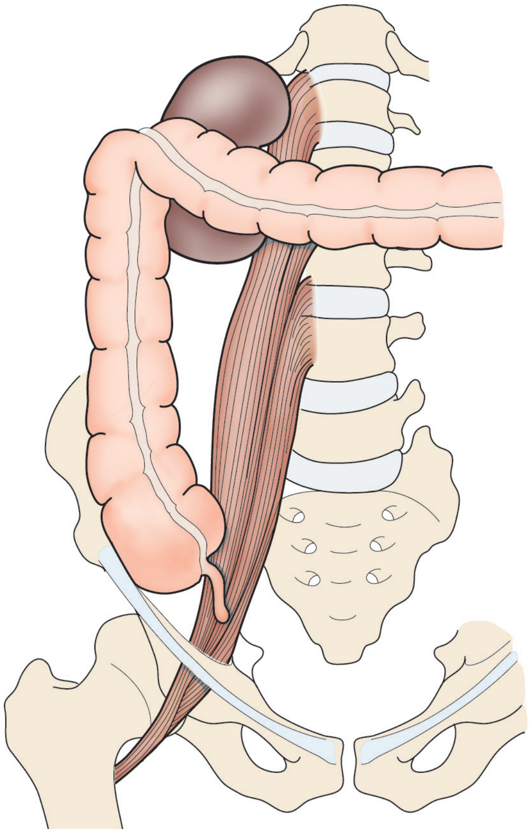


Figure 4.6 *Colon, appendix, kidney and vertebral bodies are all closely related to the psoas muscle. Infection originating from them may present as a psoas abscess tracking to the groin insertion.*

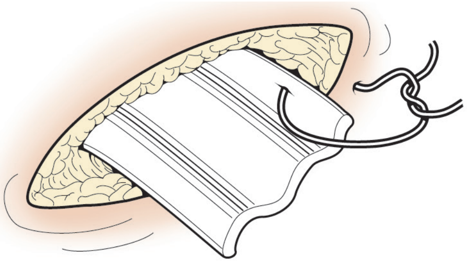


Figure 4.7 *A corrugated drain prevents premature closure of the track and of the skin. It can be secured by a suture to the wound edge.*

Anaerobic muscle infection

Clostridium perfringens, the causative organism of gas gangrene, and *Clostridium tetani*, the causative organism of tetanus, are found in soil and faeces, and these anaerobic organisms thrive in necrotic and ischaemic muscle. Gas gangrene was a common and much feared complication in the battlefields of the First World War.[4] Amputation was thus often considered a safer option than attempting to save a severely damaged limb that was already potentially contaminated with bacterial spores.

GAS GANGRENE

Clostridium perfringens multiplies in ischaemic damaged tissue. The toxins produced by the bacteria damage previously healthy tissue, which is then colonised, and the infection spreads longitudinally within muscle sheaths. The patient is usually profoundly unwell, and crepitus may be apparent from small bubbles of gas.

Prevention consists of thorough early wound toilet with removal of all necrotic tissue. A high-risk wound is then left open as described above. Although the organism is sensitive to penicillin, the use of this antibiotic for prophylaxis or treatment may be disappointing, as high blood levels do not reach the dead tissue in which the organism is multiplying.

Treatment of gas gangrene is primarily surgical for the same reason. All infected tissue must be excised as soon as the patient's general condition allows. The patient may be extremely ill, with signs of multiple organ failure, and require general resuscitation, but a surgical delay of more than a few hours will be counterproductive. This situation can pose a similar dilemma regarding the optimum timing of surgery to that encountered in patients with peritonitis, and this is discussed in Chapter 15. If gas gangrene is suspected, exploration is mandatory. In the early stages the affected muscle fibres are paler than normal, a lustreless pinkish grey shade being described. Later they become deeply congested, slate blue or frankly gangrenous. Bubbles of gas are apparent. All unhealthy and potentially infected tissue must be excised, as leaving traumatised or ischaemic tissue in the vicinity is an unacceptable risk. The possibility of saving a limb should always be considered, but unfortunately amputation is often the only safe option. Parenteral penicillin is administered at high dosage and hyperbaric oxygen therapy, if available, may be beneficial.

Tissue gas is not pathognomonic of gas gangrene as saprophytic, non-pathogenic, gas-forming anaerobes may multiply in necrotic tissue. This scenario is occasionally encountered around a retroperitoneal colonic perforation, and here excision of the necrotic tissue alone is adequate.

TETANUS

Tetanus is the other feared anaerobic infection of contaminated wounds. The incidence shows great regional variation, possibly related to soil acidity, and infection can occur after a very minor puncture wound. Immunisation, antibiotics and antiserum are all effective in its prevention. In established infection, there is no local tissue destruction, and excision of the wound has no great therapeutic merit unless indicated for other reasons. Penicillin is effective in destroying residual organisms and antiserum will neutralize any unfixed toxin. However, by the time of presentation, much of the toxin is already fixed within the central nervous system, and clinical deterioration will continue for some days despite the administration of antibiotics and antiserum. The mainstay of treatment is the control of spasms and general intensive support.

Necrotising fasciitis and Fournier's gangrene

These conditions have been discussed in Chapter 2.

MUSCLE FLAPS

Healthy muscle has an excellent blood supply, and the overlying skin derives a significant proportion of its blood supply from the muscles by 'perforating' vessels passing through the deep fascia. Many muscles have only one or two nutrient arteries supplying the whole muscle. These enter near either the muscle origin or insertion, and this anatomical arrangement allows for the isolation of a muscle, with the overlying skin if appropriate, as a 'flap'. A vascular pedicle at one end of the muscle is carefully preserved, and the other end of the muscle is separated from its origin or its insertion. This allows the musculocutaneous flap to be rotated around a vascular pedicle in order to cover a tissue defect in an adjacent area.[5] The principles underlying flap surgery are discussed in more detail in Chapter 2. Numerous adaptations of this principle have been developed in reconstructive surgery.

In managing sites that a standard flap will not reach, a free flap of muscle, with or without the overlying skin, is a possibility. The flap is detached completely and its nutrient artery and accompanying vein are anastomosed to suitable vessels in the recipient site using microvascular techniques.

The latissimus dorsi flap is described in Chapter 3 in relation to breast reconstruction surgery, the rectus abdominis flap in Chapter 13, the gracilis flap in Chapter 24 and the pectoralis flap in Chapters 10 and 11. Reconstructive flap surgery is the province of the plastic surgeon, but many general surgeons are experienced with the technique for the one or two flaps that are useful in their area of interest.

The gastrocnemius flap is useful in lower limb trauma. Tissue loss over a compound (open) fracture of the tibia is an injury that is slow to heal and prone to complications. The rotation of a musculocutaneous flap to cover the fracture site has proved very beneficial in this situation. For example, the medial head of gastrocnemius has a neurovascular bundle close to its origin. The muscle can be divided distally at the musculotendinous junction and swung medially to cover an exposed fracture of the upper tibia. The functional defect is compensated for by the other muscles in the flexor compartment. If a muscle flap is used without overlying skin, a split-skin graft can then be used to cover the muscle.

SOFT TISSUE MALIGNANCY

Malignant soft tissue tumours are sarcomata that metastasise via the bloodstream and not via the lymphatics. Treatment of the primary lesion must be adequate, or local recurrence is common, but no benefit is gained by lymph node dissection. The apparent 'capsule' of these sarcomata is merely a layer of compressed tumour cells and, therefore, 'marginal' excision in the natural plane just outside this capsule inevitably leaves a tumour bed that is contaminated with malignant cells. Surgical excision should therefore include a circumferential margin of normal tissue. When a sarcoma arises within a muscle the excision should usually include the whole muscle or fascial compartment. Frequently, an initial excision has been undertaken for what was believed to be a benign lump, and a second more radical operation is indicated once there is confirmatory histology of malignancy. Limb amputation can usually be avoided. Radiotherapy may be an alternative to radical surgery in tumours that are highly radiosensitive. It is generally accepted that patients with these relatively rare tumours should be managed in centres with a special interest.

Pulmonary metastases are usually the first indication of metastatic spread, and occasionally surgical removal of isolated metastases in liver or lung can still offer the chance of a cure. Chemotherapy and radiotherapy have an increasing role, both in adjuvant and in palliative therapy.

TENDON REPAIR

A tendon is a condensation of fibrous tissue in continuity with a muscle. The origin of a muscle is commonly fleshy from a wide area of bony cortex, but if it arises from a localised area it may be tendinous; for example, the common extensor tendon, arising from the lateral epicondyle of the humerus. The insertion of most muscles is tendinous, as the muscle is commonly inserted only into a localised area of bone. The tendon may be short in proportion to the muscle belly (e.g. the patella tendon) or long, as in the tendons of the finger flexors and extensors.

A tendon may be severed by a laceration, and the long flexor and extensor tendons to the fingers are particularly vulnerable owing to their superficial position. Tendon rupture can also be caused by a blunt force. This may represent excessive force on a normal tendon or a minor strain on a degenerative tendon. A tendon may also disrupt at its attachment to bone or it may avulse the fragment of bony cortex to which it is attached.

If no action is taken after tendon disruption, the muscle tone pulls the tendon ends apart. Any healing will be with a shortenend muscle belly and an attenuated tendon with a resultant diminution of function. Sometimes the ends can be approximated by extension, or flexion, of the relevant joint, but results are better with a formal repair. The tendency for sutures to cut through the fibres is overcome by the techniques shown in Figure 4.8. However, the repair must be of adequate strength to overcome the forces channelled through the tendon. Suture configurations that result in at least four 'core' strands crossing the defect are now favoured (Figure 4.8b) and for the large Achilles tendon, a multistrand core suture is recommended. A continuous circumferential epitendinous suture then adds additional strength (Figure 4.8c).

Non-absorbable monofilament or multifilament sutures are recommended. If the tendon has severed at its bony attachment, tendon to bone fixation is required. This can be achieved with a suture anchor (a specially designed bone screw) or by simply drilling a hole through the bone and passing a suture through the hole. Two other methods are shown in Figure 4.9. A spontaneous rupture of a degenerative tendon can seldom be satisfactorily repaired, and the choices include acceptance of the disability, an attempt at a repair that will probably fail, or a tendon transfer or tendon graft operation.

Even after a tendon repair, splintage of the joint is usually required to reduce tension during healing. For example, an

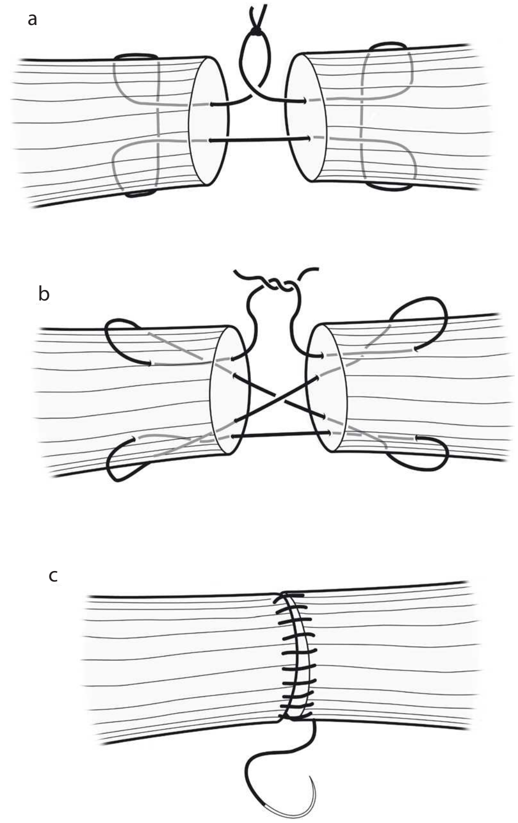


Figure 4.8 *The propensity of a suture to cut through a tendon can be minimised by the locking loops that grip the outside of the tendon. (a) A classical method with 2 core strands – note the buried final knot. (b) A 4-core suture configuration. (c) An additional finer continuous suture is inserted circumferentially in the epitendon.*

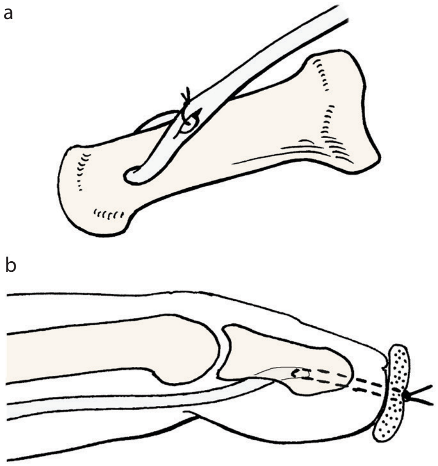


Figure 4.9 *(a) The tendon has been passed through a hole drilled in the bone and sutured to itself. (b) A suture passed through the tendon and out through the terminal phalanx to the skin is tied over a button. After 3–4 weeks the suture and the button are removed.*

Achilles tendon rupture treated surgically may still require splintage of the ankle in plantar flexion for 6 weeks.

EXTENSOR TENDONS IN THE HAND

Extensor tendons in the hand heal well and may be repaired primarily by simple apposition. Some surgeons favour an absorbable suture, as it is impractical to bury a knot in these flat tendons. Avulsion of the extensor tendon from the base of the terminal or, less commonly, the middle phalanx of a finger can be successfully treated conservatively by splinting the affected joint in extension for 4–6 weeks.

EXTENSOR POLLICIS LONGUS

Repair of a spontaneous rupture of the extensor pollicis longus tendon is seldom practical. It may be ignored or a tendon transfer performed. Eric Farquharson had a spontaneous rupture of his extensor pollicis longus a few years before retirement. Within 2 weeks he had adapted sufficiently to return to operative surgery – much earlier than would have been possible after a tendon transfer.

FLEXOR TENDON INJURY IN THE HAND

Current advice for managing a flexor tendon injury in the hand is that primary repair combined with early active motion rehabilitation under supervision offers better results than delayed grafting.[6] Early referral is therefore indicated, if at all possible. Surgical repair can give disappointing results, even when undertaken by specialist surgeons. This is especially so in Zone 2 where the tendons and their synovial sheaths are within the fibrous flexor sheaths (Figure 4.10); here, dense permanent adhesions commonly form during healing, especially if rigid splinting is employed. It is recommended that no repair is attempted when there is an isolated division of a superficial tendon within Zone 2. If both flexor tendons are divided, only the profundus tendon should be repaired. Success with flexor tendon repair is dependent on the repair being strong enough to allow early protected movement. One of the key factors determining this strength is the number of core strands that cross the repair site. Various suture techniques have been described, but a 4-strand core suture with a material such as 4/0 Ethibond™ is satisfactory (Figure 4.8b). The epitendinous suture, with for example 6/0 nylon, not only adds 20 per cent to the strength of the repair, but also improves gliding and reduces the incidence of gap formation, which is the initial event in repair failure. Tendon repairs are weakest between postoperative days 6 and 12 and the rupture rate can exceed 10 per cent. After finger tendon repair, splintage to protect against excess force is required for 6–8 weeks.

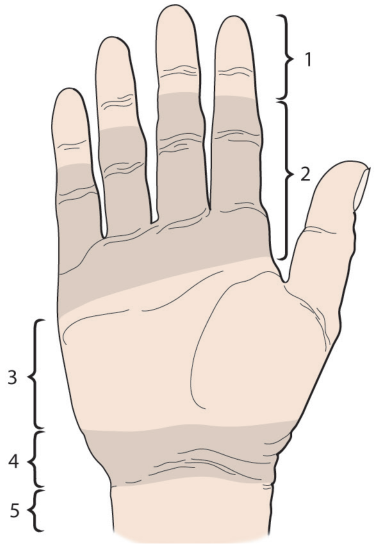


Figure 4.10 *Primary repair of flexor tendons in Zones 1, 3 and 5 is satisfactory, whereas repair in Zone 2 and, to a lesser extent, in Zone 4 is often disappointing owing to the formation of dense adhesions.*

Kleinert *et al.* (1967) reported that primary repair of Zone 2 injuries had a good outcome if followed by early postoperative mobilisation with active extension and passive flexion in a 'lively' elastic band splint.[7] Meticulous postoperative care remains the key to a good functional outcome. Controlled mobilisation limits restrictive adhesions and improves tendon healing biology. Partial tendon lacerations of up to 50 per cent can be treated by bevelling the laceration to prevent triggering. Early active movement is important, but heavy loads must be avoided for 6 weeks. Partial lacerations of over 50 per cent should be repaired. Delayed presentation of flexor tendon injuries does not exclude primary repair if there is no segmental loss of the tendon, a good range of passive movement in the joints and no associated bony or soft tissue problems.

If the injury presents after more than 3 weeks, tendon grafting is the treatment of choice, because the muscle belly shortens and the tendon ends scar and form adhesions. Excision of the damaged tendons and grafting can be a single- or two-stage procedure. The fibrous flexor sheath is excised except for the major pulleys, which are left *in situ* to prevent bow stringing of the tendon graft. The superficialis tendon is excised and the profundus tendon excised from Zone 2. The tendon graft is then carefully drawn through the pulleys. The two tendon suture lines, to the distal profundus stump and to the proximal tendon in the palm, are thus outside Zone 2, which is particularly prone to fibrosis.

INFECTIONS OF THE HANDS AND FEET

Hand infections

Treatment is dominated by the need to prevent stiffness and the subsequent loss of function. The hand, whether injured by infection or trauma, is at high risk of a poor long-term functional outcome if restoration of mobility is delayed. Correct splintage combined with elevation to minimise swelling during the early phase, followed by intensive physiotherapy, is essential (Figures 4.11–4.13). Early treatment of an infected hand with an appropriate antibiotic and elevation is often successful but, if rapid resolution does not occur, trapped pus must be suspected and released. It is not always immediately apparent in which compartment the pus is trapped, as the whole digit or hand will swell. Even the eventual 'pointing' may mislead if the anatomy is not appreciated (Figures 4.14 and 4.15).

SYNOVIAL SHEATH INFECTIONS

Infection within the synovial sheaths of the flexor tendons (Figure 4.16) can result in fibrous adhesions within the sheath or even sloughing of the tendon. The sheath should therefore be explored if pus is suspected or if complete resolution has not occurred within 48 hours of antibiotic treatment. Surgical exploration is carried out through two skin crease incisions – one placed over the proximal sheath and the other in the distal skin crease of the finger over the distal sheath. The sheath is drained and then irrigated with saline via a fine catheter, which can be left *in situ* for further irrigation over the ensuing 24–48 hours.

OTHER SOFT TISSUE INFECTIONS IN THE HAND

Early diagnosis and antibiotic therapy have reduced the need for surgical intervention, but once pus has formed it should be drained. It should be remembered that deep pus may be difficult to diagnose if it fails to point superficially, and that pus pointing superficially may be associated with a deeper collection that also requires drainage. For example, a *paronychia* may extend under the nail, necessitating nail avulsion

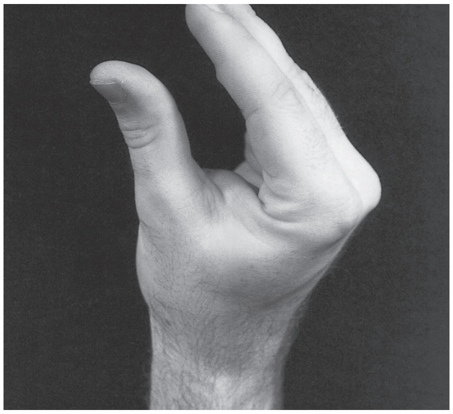


Figure 4.11 *The 'position of immobilisation' for the hand. Relevant capsular structures are held at maximum length to prevent joint contractures. The wrist is slightly dorsiflexed, the interphalangeal joints are extended and the metacarpophalangeal joints are flexed. The thumb lies parallel to the fingers.*

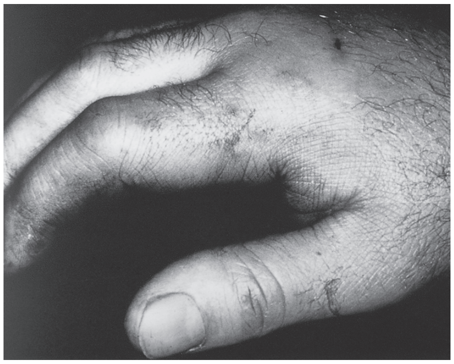


Figure 4.12 *Injured joints seldom lie naturally in either the 'position of immobilisation' or the 'position of function'. Injured hips and knees lie flexed and the injured hand adopts this position (cf. Fig. 4.11). The hand must be elevated to reduce swelling and splinted in the correct position to prevent secondary contractures.*

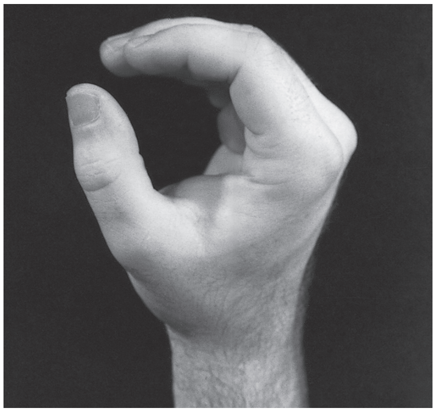


Figure 4.13 *The 'position of function'. A hand fixed in this position is still of functional use. This is not the correct position for immobilisation unless loss of joint movement is inevitable.*

Figure 4.14 *Infections that may affect a digit. A = tendon sheath infection; B = septic arthritis; C = paronychia; D = subcutaneous infection with a subcuticular 'collar stud' extension; E = subcuticular abscess; F = pulp space infection; G = osteomyelitis; H = apical pulp space infection.*

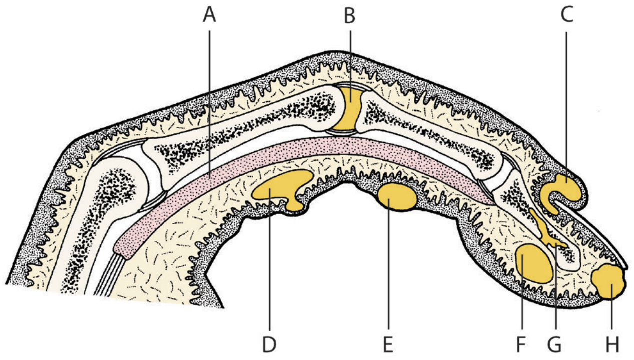
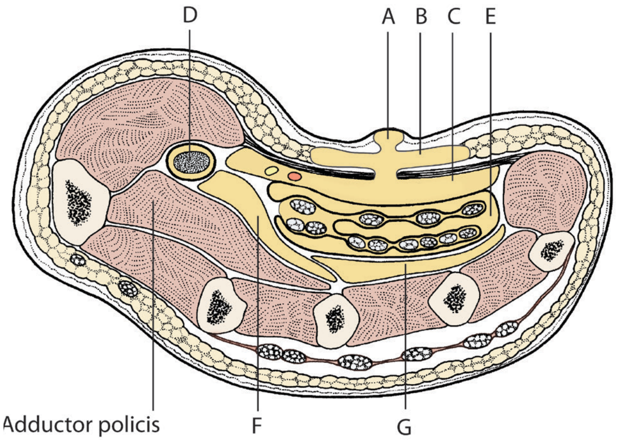


Figure 4.15 *The anatomy of hand infections, shown on a transverse section. A = subcuticular palmar abscess; B = subcutaneous palmar abscess; C = subaponeurotic palmar abscess; D = tendon sheath infection (radial bursa); E = tendon sheath infection (ulnar bursa); F = thenar space; G = deep mid-palmar space.*



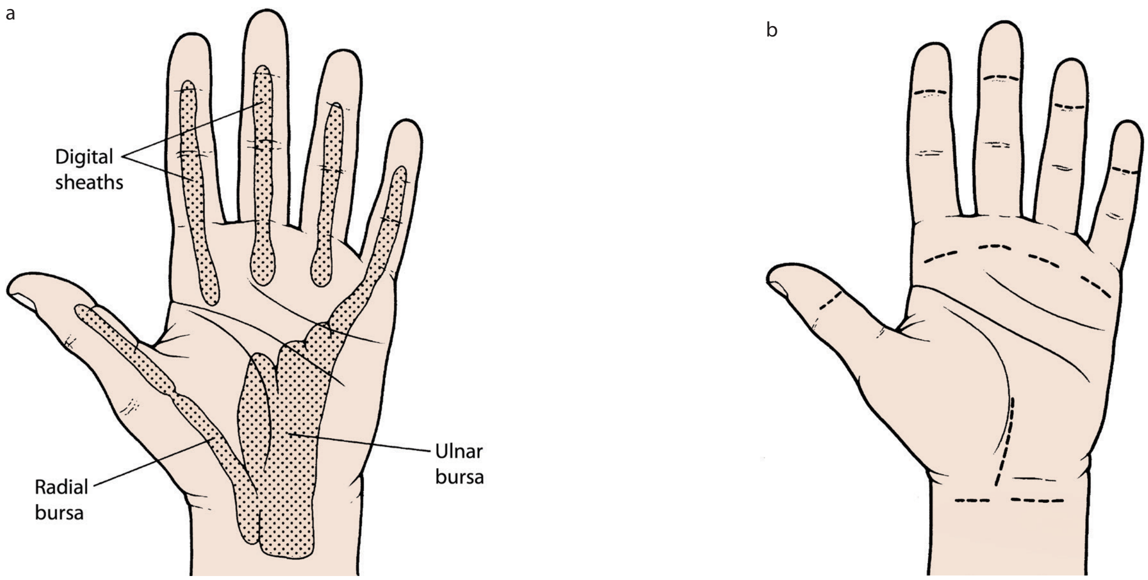


Figure 4.16 *(a) The flexor tendon sheaths. (b) The incisions for drainage of tendon sheath infections.*

for adequate drainage, while a *superficial septic blister* may connect with a deeper subcutaneous or pulp space collection. Between the palmar aponeurosis and the flexor tendons is the *superficial middle palmar space*. An infection of this space is usually caused by a penetrating wound of the palm; this presents as a 'collar stud' abscess in the palm (see Figure 4.15) and should be drained anteriorly. Behind the flexor tendons are the *deep mid-palmar space* and the *thenar space*. Infection within these spaces is less common and initially presents with a generally swollen hand, this often being more noticeable on

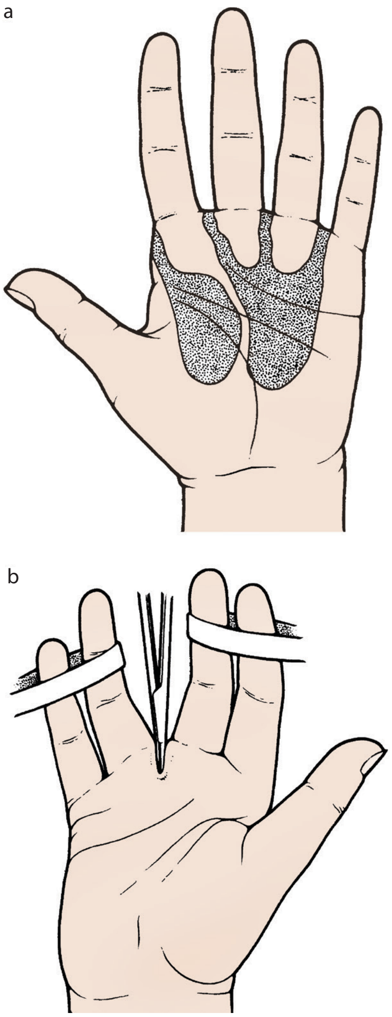


Figure 4.17 *(a) The thenar and deep mid-palmar spaces communicate with the web spaces via the lumbrical canals. (b) Drainage is via the web space.*

the dorsum. Drainage is undertaken from the web space, which is also where the pus will eventually point after tracking via the lumbrical canals (Figure 4.17).

Foot infections

In contrast to the hand, where the predominant concern is regarding stiffness and loss of function, infections in the feet carry a significant risk of loss of a limb. Penetrating trauma is common in the barefoot farm worker. The wound is contaminated by soil and then often neglected until there is established deep infection and even infected gangrene. Adequate drainage of pus is essential, combined with removal of dead tissue and contaminants. Systemic antibiotics and repeated local treatment are continued until the infection has settled and healing has commenced. Only then should secondary suturing or reconstruction be considered. Amputation in the presence of infected gangrene is discussed in Chapter 5. In the developed world most foot infections follow very minor trauma in diabetic patients. Diabetic neuropathy may have rendered the patient oblivious both to the trauma and to the early stages of infection. Impaired circulation, from both large vessel atheroma and diabetic microangiopathy, reduces tissue resistance and the raised blood glucose provides an excellent environment for bacteria. Underlying pus must be considered if prompt resolution does not occur with appropriate antibiotics. Associated osteomyelitis of phalanges and metatarsal heads and septic arthritis may also occur early. Pus can be drained from a web space but often a ray amputation is required for a gangrenous toe or when additional bone or joint infection has become established (see also Chapter 5).

ELECTIVE TENDON SURGERY

Tenotomy for access

A tendon may have to be divided to allow access for surgery. It is then repaired at the end of the procedure. Examples include tendon division to allow full exposure of the popliteal artery for arterial reconstruction, and the tendon division necessary to enable transposition of the ulnar nerve to the flexor aspect of the elbow.

Tenotomy and tendon lengthening

Here, the techniques rely on the principle that natural healing of a divided tendon occurs with lengthening as the muscle tone distracts the cut ends. Whereas a simple tenotomy may be satisfactory in some circumstances, a formal tendon-lengthening procedure is superior when the muscle is functionally important (Figure 4.18). *Sternomastoid* tenotomy may be used to correct congenital torticollis. Division of the common extensor tendon from the lateral humeral epicondyle may be undertaken for an intractable '*tennis elbow*'. *Adductor*, *hamstring* and *Achilles* tendons can all be divided or lengthened to allow correction of a flexion deformity. Unfortunately, the tendon that is felt as the tight band restricting movement is often only part of the problem, and a further soft tissue release may be required. This is seen both in the treatment of congenital talipes equinovarus and in the *late contractures* after neglected trauma and paralysis that are so often encountered in areas with poor access to medical care. In the latter situation there is often a fixed flexion of the hip and knee with an equinus ankle deformity. The surgeon is aiming for a plantigrade foot and a weight-bearing limb,

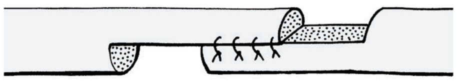


Figure 4.18 *A tendon-lengthening technique suitable for a short Achilles tendon.*

with possible caliper support. Very careful assessment before surgery is essential. Shortened major vessels and nerves crossing the flexor aspect of the joint may still prevent extension. In addition, the correction of an equinus deformity may be counterproductive if it is compensating for a shortened limb.

Tendon transfers

Tendon transfers are used to restore balanced active movement. This may have been lost as a result of muscle or tendon damage or there may be an imbalance from neurological disease. The muscle must be strong enough for its new role, with adequate amplitude of motion in a similar direction. It is also essential that it can be spared from its original function. *Extensor indicis* fulfils these criteria when used to replace a ruptured *extensor pollicis longus*. Assessment is essential before embarking on surgery, and any fixed deformity must have been corrected. Tendons may be joined, as shown in Figure 4.19.

The *tibialis posterior* tendon may be transferred to correct the drop foot of paralysed peroneal muscles. The distal muscle and proximal tendon are mobilised above and behind the medial malleolus. The tendon insertion into the navicula is divided through a separate incision. The tendon is transferred anteriorly and, through a separate incision over the base of the fifth metatarsal, is attached to the paralysed peroneus brevis. This is a useful technique for surgeons practising in countries with a high incidence of polio or leprosy.

Tendon grafts

The non-essential tendons of palmaris longus and plantaris can be used as grafts to bridge gaps in essential finger flexor tendons, as discussed above.

Tendon release

Stenosing tenosynovitis prevents free movement of a tendon within its sheath. In *trigger finger or thumb* there is a nodular swelling on the flexor tendon that catches as it is pulled under the proximal end of the fibrous flexor sheath during extension of the digit. Surgical release is indicated if steroid injection fails. It is performed through a short transverse or longitudinal incision, just distal to the distal transverse palmar skin crease; the neurovascular bundles must be protected. Extensor pollicis brevis and abductor pollicis longus may be trapped in the first compartment of the extensor retinaculum at the wrist. If a steroid injection fails to relieve pain and swelling, surgical release can be undertaken. Care must be taken of the terminal branches of the radial nerve, as intractable pain can occur if they are damaged. Sometimes, the compartment contains subdivisions of the nerve, which must be sought and released.

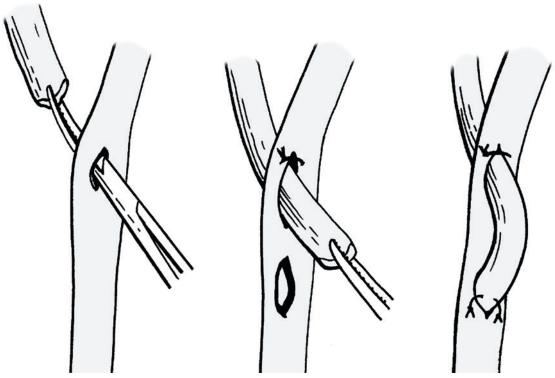


Figure 4.19 *A technique for joining two tendons.*

SURGERY OF LIGAMENTS AND JOINTS

Consideration must always be given to the position of any injured or inflamed joint, as even a healthy immobilised joint may stiffen. If a joint requires splintage, it should be immobilised in a position that holds the relevant capsular structures at their maximum length, rendering contractures less likely (see Figure 4.11). This is often a different position from that which the injured joint assumes naturally (see Figure 4.12). If long-term loss of movement and even bony ankylosis are inevitable, it is important that the joint is in the best position for any subsequent use of the damaged limb (Figure 4.20; see also Figure 4.13).

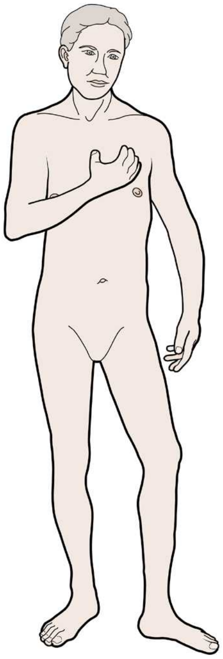


Figure 4.20 *The 'position of function' in the lower limb is with the hip extended, the knee flexed to 10 degrees only and the ankle dorsiflexed to 90 degrees. Elbows fixed in acute flexion allow patients to feed themselves; extended elbows allow them to attend to toilet needs. When joint destruction is anticipated after an advanced septic arthritis or injury, splintage to obtain a joint position consistent with a functional limb is essential.*

Ligaments are condensations of fibrous tissue on which the stability of a joint depends. Some, such as the cruciate ligaments of the knee and the ligament to the femoral head, are within the joint, and the latter also carries an important nutrient artery. More often they are outside the joint and are closely associated with the joint capsule. In traumatic rupture the ligament itself may tear or it may avulse a fragment of bone from its insertion. Disruption of a ligament should be suspected if there is a haemarthrosis or if a small fragment of bone is seen on X-ray in the vicinity of a ligamentous insertion. Ligament disruption and instability of a joint are confirmed on stress X-rays, taken under general anaesthesia to overcome the stability being maintained by the surrounding muscles.

Repair of ligaments and joints

Immediate repair using similar techniques to tendon repair may be performed, but as delayed surgical reconstruction has generally produced better results than immediate repair, the initial treatment is normally conservative. There is no muscle distraction of the cut ends of a ligament and therefore a plaster cast to prevent any 'opening' of the joint may sometimes allow satisfactory healing. When healing is unsatisfactory and the joint is unstable, a late reconstruction is undertaken. This has proved especially effective for the anterior cruciate ligament. These operations, though, are for experts in the field, and an occasional surgeon would expect poor results.

Pyogenic arthritis

The management of joint infections often forms only a small part of the practice of a specialised orthopaedic surgeon, but in some areas of the world they are common and a major cause of long-term disability. Urgent action is required to save the joint. Differential diagnosis from traumatic haemarthrosis and gouty arthritis may be obvious clinically, but if pus or blood is suspected, aspiration is essential to establish the diagnosis. A needle is introduced through an area of locally anaesthetised skin. If pus or blood is encountered, a wide-bore needle is required to ensure adequate drainage. Needle access to a swollen joint is normally straightforward, but consideration must be given to avoiding overlying vessels and nerves. The hip joint, however, can be more difficult as it is deep and a joint effusion does not produce obvious swelling. A satisfactory method is to introduce the needle just above the tip of the greater trochanter and pass it upwards and medially, in the line of the femoral neck, until the joint is reached. (X-ray guidance is helpful if available.)

When all blood or pus has been evacuated, the joint is irrigated with normal saline. Septic arthritis requires high doses of antibiotics – preferably given intravenously – and repeat aspirations and irrigation should be performed daily until inflammation has settled. If the pus is thick and cannot be aspirated, the joint requires formal exploration for drainage. Consideration should be given to the best position for splintage (see above).

In a young child, if there is as yet no epiphyseal barrier to infection, septic arthritis may be associated with osteomyelitis. Failure to recognise and treat the additional pathology may have serious consequences (see Chapter 5).

Elective surgery of joints

Ganglia

These arise most commonly from the wrist and interphalangeal joints. Often, no surgery is indicated and some will disappear spontaneously as a result of rupture. This can be attempted therapeutically by aspiration of the contents with a wide-bore needle under local anaesthesia, followed by further disruption of the wall of the ganglion by multiple punctures with the same needle. If a ganglion is to be excised, it must be traced down to the joint capsule where, if there is a connection, it should be transected but left open. Adequate anaesthesia and a bloodless field are mandatory. Even if the excision is complete, recurrences are common.

Surgery within joints

This includes reconstructive ligament surgery, trimming of meniscal tears, removal of loose bodies and synovectomies. Many open surgical procedures have been virtually replaced by minimally-invasive techniques with the arthroscope. This is not surgery in which a general surgeon should be involved without additional orthopaedic training.

Arthrodesis and excision arthroplasty

Ankylosis, or spontaneous bony union, may develop across a joint that has been severely injured by trauma or infection. Ankylosis may give a good functional result if fusion occurs in the position of function. *Arthrodesis,* in which a joint is surgically obliterated, inducing bony union, is based on the same principle. A severely diseased, painful joint may be excised as an *excision arthroplasty,* in which the aim is to obtain a fibrous rather than a bony union. These procedures are discussed briefly in Chapter 5, as they may be of value to the isolated generalist.

Joint replacement

This is now a standard technique for hip and knee joints badly damaged by degenerative and other pathologies. Other joint replacements are performed less frequently. Orthopaedic operative texts cover this enlarging field.[1]

NERVE INJURIES

A major peripheral nerve is made up of a large number of fibres – for example, there are over 10,000 in the median nerve in the forearm. Each fibre consists of an *axon* surrounded by its Schwann cell sheath. The axon is the process of a nerve cell, the main body of which lies within the dorsal root ganglion or within the central nervous system. The peripheral nerves carry, to a varying degree, fibres concerned with motor, sensory and autonomic functions. Groups of nerve fibres are aggregated into bundles, or fascicles, which are surrounded by a thin layer of connective tissue. There is a strong and distinct layer of connective tissue, the *epineurium,* which surrounds the fascicles that make up a nerve trunk (Figure 4.21). The connective tissues of a peripheral nerve are surprisingly strong so it is not uncommon to find the major nerves as the only intact structures in a severely injured limb. The peripheral nerves are supplied by many small arteries, which communicate freely within the nerve. It is possible, therefore, to mobilise quite long lengths of nerve without damaging the blood supply.

Nerve injuries may be divided into three degrees of severity:

- In *neurapraxia* the axons are not disrupted, but nerve conductivity is temporarily lost. Recovery occurs spontaneously within hours or days of the injury.
- In *axonotmesis* the axon is disrupted but the supportive connective tissues of the nerve remain in continuity. The axon has to regrow along the intact sheath and there is no functional recovery until it reaches the end organ. The growth rate is around 1 mm a day.
- In *neurotmesis* the nerve is completely divided. No recovery occurs unless surgical repair is undertaken as the ends retract, the axonal outgrowths fail to find an axonal sheath and scar tissue forms.

Surgical repair is an attempt to convert a neurotmesis into a situation similar to an axonotmesis, but the result is never as good, as many axons still fail to grow down a sheath. In addition, sensory regrowth towards a motor endplate, and vice versa, is of no functional benefit.

Nerve repair

A loss of nerve function in a *closed injury* is usually either a neurapraxia or an axonotmesis, and the initial management can be conservative. If recovery does not occur within a few days, the injury is probably an axonotmesis and there will be a long wait as the axons regrow. However, the possibility that the nerve is divided should be considered, even in a blunt injury. If doubt continues, surgical exploration should be considered. The integrity of a nerve in the vicinity of any *open injury* should be checked and a loss of nerve function distal to a wound always suggests a divided nerve. When the wound is explored the severed nerve ends are identified and a decision is then made as to whether to proceed with a primary nerve repair. A bloodless field with a tourniquet (see Chapter 1) provides the best conditions for nerve repair, but a tourniquet may be contraindicated in an extensively damaged limb in which additional ischaemic insult should be avoided. Primary repair may be the best option, but only in clean, incised wounds of limited extent and where surgeons have the necessary experience, instruments and time at their disposal. Most general surgeons will wish, therefore, to enlist the help of an orthopaedic or plastic surgical colleague with special expertise and, if not available, to opt for secondary repair. An isolated general surgeon may have limited experience, combined with a lack of fine equipment, but, if referral is impractical, will have to proceed with either primary or secondary repair.

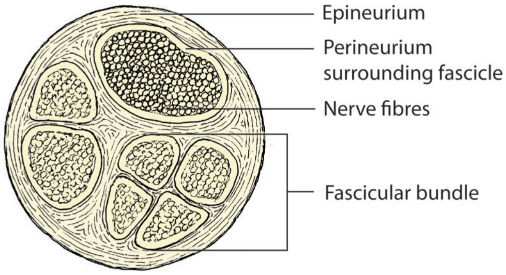


Figure 4.21 *Diagrammatic cross-section of a peripheral nerve.*

If repair is to be delayed, the nerve ends should be prevented from retraction. If the ends can be approximated without tension, they can be apposed with two or three inert sutures to await a more formal repair. Correct orientation at this stage may be easier than subsequently, and should be attempted and documented. If the severed ends cannot be apposed, they should be fixed to surrounding tissue to prevent further retraction.

Nerve repair, if at all possible, should be performed with the help of some form of magnification, either loupes or an operating microscope, to prevent further damage to the nerve by clumsy dissection and to ensure accurate orientation of the nerve and placement of sutures. Sutures should be of a relatively inert material, such as nylon or Prolene™, and be very fine (8/0 or finer). Silk and absorbable sutures provoke an inflammatory response and should not be used.

PRIMARY REPAIR

For primary suturing only minimal trimming of the nerve ends is required. This is carried out with a sharp razor blade with the nerve resting on a firm surface. Correct orientation of the nerve is facilitated by noting the arrangement of the fascicular bundles within the nerve (Figure 4.21) and the presence of any blood vessels on the surface. Intraneural dissection and sutures cause further fibrosis and should be avoided; the repair is with epineural sutures. The first two sutures may be left long and held to steady and rotate the nerve; alternatively, initial ‘guide sutures’ can be placed as illustrated in Figure 4.22. Excessive suturing should be avoided. For example, six to eight sutures are sufficient for the median nerve and two to three for a digital nerve.

SECONDARY REPAIR

At a secondary repair, it is safer first to identify the nerve, both proximal and distal to the scar tissue, and only then to dissect the injured site. If the ends have been aligned at the original exploration, guide sutures placed before excising the bridge of neuroma and scar tissue will facilitate maintaining correct alignment; in addition, these sutures can be used to draw the ends together. Both ends must be cut back to undamaged nerve beyond the scar tissue and the neuroma (Figure 4.22b). This is recognised when the nerve bundles pout separately from the cut surface and may require up to 1 cm of excision. Orientation, alignment and suturing are carried out as for a primary repair. The epineurium is thicker than in a primary repair and suturing is easier. Mobilisation of the ends will be required to achieve apposition without tension, but if the defect is greater than 2–3 cm, direct suturing is not possible without shortening the course of the nerve by transposition or by flexion of a joint. Alternatively, a nerve that is relatively redundant for normal function, such as the sural or saphenous, is used as a graft to bridge the gap. Techniques for nerve grafting and for the repair of partially severed nerves are for specialists with expertise in the field, and will give disappointing results when used by generalists.

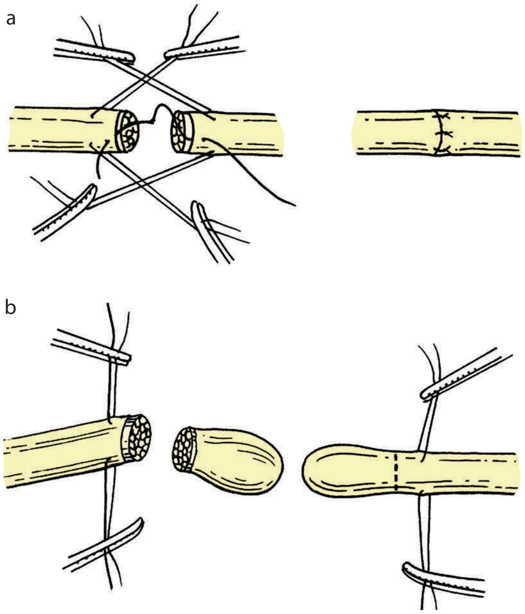


Figure 4.22 *Nerve repair is by epineural sutures, and correct orientation of nerve bundles is essential. (a) The initial guide sutures hold the orientation and prevent inadvertent subsequent rotation of one end. They can also be used to rotate both ends of the nerve together so that the posterior sutures can be inserted.*
(b) In secondary repair the neuroma must first be excised.

After any nerve repair, immobilisation is indicated for 3 weeks to protect the suture line from tension. Flexion of a joint may be required to prevent initial tension on a shortened nerve, but marked flexion should be avoided by the use of nerve grafts. Subsequent extension of the joint must be a controlled slow increase over several weeks to prevent disruption of the repair. While awaiting axonal regrowth, whether after axonotmesis or nerve repair, the patient must be shown how to use passive movements to retain joint mobility. Advice must also be given to minimise the risk of accidental injury to skin that has no protective sensation. Splintage to maintain function and prevent contractures may also be needed during the recovery period.

Good functional recovery is dependent not only on the technical success of the repair but also on the distance the axons have to grow to reach the end plates, and whether the nerve is mixed or mainly either sensory or motor. The technical challenges and the functional results of repair of different nerves therefore vary.

Facial nerve

The facial nerve may be damaged or intentionally sacrificed for oncological reasons during parotid surgery. Direct apposition is seldom possible, but good results can be achieved with nerve grafts. If this is unsuccessful, management can be with dynamic muscle transfer. Neurapraxia after a superficial parotidectomy is not uncommon, but if the surgeon is confident that all branches of the nerve were identified and preserved, there can be reasonable confidence that function will recover, commonly within a day or two if there has been no axonal disruption (see also Chapters 10 and 11).

Recurrent laryngeal nerve

The recurrent laryngeal nerve may be injured in thyroid surgery (see also Chapter 10). Neurapraxia will recover but a severed nerve causes permanent cord paralysis, with a resultant deepening and reduced force to the voice. A bilateral injury results in both cords drifting medially. A tracheotomy may have to be performed to maintain the airway. Any form of nerve reconstruction is very difficult.

Brachial plexus

Injury to the brachial plexus is most often seen after motor cycle accidents and is caused by a severe traction force that may also have damaged the proximal subclavian artery. The injury is often of mixed severity, with some portions of the brachial plexus suffering only neurapraxia, while other portions have axonal disruption or are completely severed. The prognosis is therefore very varied. Surgical repair of a severed nerve may not be practical, as the commonest site of damage is an avulsion of the roots from the spinal cord. Some surgeons advocate early exploration, but as access is difficult and often little can be achieved in the way of a repair, this is unlikely to appeal to the generalist who, with limited experience of the problem, is in danger of causing more harm than good. Patients should be referred for a specialist opinion if this is available. Obstetric brachial plexus palsy, associated with shoulder dystocia during delivery and presenting in the neonatal period, will often resolve spontaneously.

Radial nerve

The radial nerve is vulnerable to damage from the bone ends in a humeral shaft fracture. Repair of the nerve may produce good results as it is mainly a motor nerve. The distance to the endplates, however, delays recovery for a year or more and a splint for wrist drop is required. If the nerve repair is unsuccessful, the wrist drop can be treated by tendon transfer.

Median nerve

The median nerve is most often divided in a laceration of the wrist or forearm. The radial or ulnar artery may also have been divided and additional tendon damage is also common. At the wrist the median nerve is flattened and easily mistaken for a tendon. It is therefore important that exploration, as well as repair, is undertaken under optimum conditions; this requires a bloodless field with a tourniquet. Postoperative flexion of the elbow reduces tension on a median nerve repair at the wrist and is preferable to palmar flexion of the wrist. If the wrist is held in acute flexion during healing, the adherence of the nerve at the site of injury to adjacent tissues can cause traction problems when the wrist is mobilised.

Ulnar nerve

The ulnar nerve may be divided at the wrist, where the challenges in diagnosis and successful repair are similar to those encountered in median nerve damage. If the ulnar nerve is severed at the elbow, it is advisable to bring the divided ends anteriorly for a tension-free repair. Anterior translocation of an intact ulnar nerve is described below.

Sciatic nerve

Repair of the sciatic nerve, although technically straightforward, gives poor functional results.

Autonomic nerves

Repair of autonomic nerves is not a surgical option, as these nerves consist of non-myelinated nerve fibres; effective axonal regrowth is not possible in the absence of axonal sheaths, even if the ends are approximated. Pelvic surgery endangers both the sympathetic and parasympathetic nerves to the bladder and sexual organs and great care must be taken to cause the minimum of damage.

Nerve infections

In the early stages of a *herpes zoster* infection (shingles) the dermatome pain precedes the skin rash and can cause major diagnostic confusion. *Poliomyelitis* presents to the surgeon after the acute illness with residual limb paralysis and deformity. The nerve infections in *leprosy* also lead to paralysis and deformity, but in addition the loss of sensation results in distal soft tissue damage. The surgical implications of polio and leprosy are substantial, but the surgery required is not on the nerves themselves.

ELECTIVE SURGERY OF NERVES

Nerve release

Nerve release is indicated if a nerve is suffering repeated trauma or constriction resulting in an 'entrapment' neuropathy. The neuropathy may take the form of pain, altered sensation or muscle weakness and wasting. Conservative measures include rest and/or local steroid injection to reduce local inflammatory swelling, but surgical release is still often indicated. It should not be delayed until irreversible damage to the nerve has occurred.

Carpal tunnel release

This procedure is indicated when conservative management has failed to relieve median nerve compression. The operation is normally performed under local anaesthesia. The incision (Figure 4.23) is deepened through the palmar fascia to expose the flexor retinaculum. The flexor retinaculum must be divided completely to release the median nerve and the proximal edge of the retinaculum must be sought under the skin if the skin incision stops short of the wrist crease. The thenar motor branch is at risk, and an incision to the ulnar side of the nerve is safer than directly over it. Only the skin is sutured.

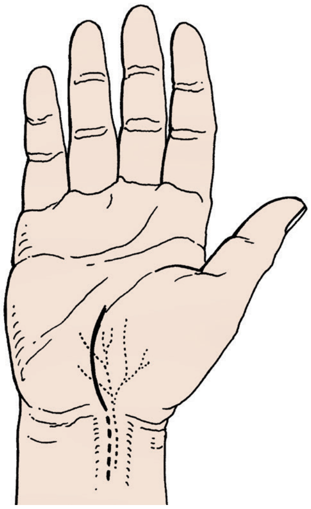


Figure 4.23 *The incision for carpal tunnel decompression is placed slightly towards the ulnar side of the midline to avoid the palmar cutaneous branches of the median nerve. The skin incision can stop short of the wrist crease.*

Ulnar nerve decompression

Ulnar nerve decompression, *in situ* in the cubital tunnel, will usually relieve entrapment symptoms. Transposition to the front of the elbow shortens the course of the nerve and reduces tension, but is a more complex procedure, as the common flexor tendon has to be divided and then repaired after the ulnar nerve has been transposed. Additionally, to ensure sound healing of the tendon, the elbow should be immobilised for 3 weeks.

Lateral cutaneous nerve

The lateral cutaneous nerve of the thigh may be trapped under the inguinal ligament, and symptoms usually settle with steroid injections.

Thoracic outlet syndrome

Thoracic outlet syndrome presents with a mixed pattern of nerve and arterial compression. A prominent 1st rib or an accessory cervical rib causes trauma predominantly to the axillary artery and the C8 and T1 nerve roots, whereas prominent scalene bands may traumatise C5 and C6. The place of surgery in this condition, and the operative options, are discussed in Chapter 7.

Intercostal nerves

Intercostal nerves may be trapped as they emerge from under the costal margin, but more commonly the entrapment occurs as they enter the rectus sheath. Surgical release is seldom indicated, as symptoms usually settle with steroid injections, but they can present diagnostic problems.

Nerve division and ablation

Intentional surgical division of nerves is now restricted to vagotomies and sympathectomies. Historically, *phrenic nerve*-crushing techniques were used to cause an axonotmesis. The diaphragm was paralysed and 'rest' of the tuberculous lung was believed to encourage healing. As the axons regrew the function recovered.

Vagotomies

Truncal, selective and *highly selective vagotomies* are discussed in the upper gastrointestinal chapters.

Cervical sympathectomy

Cervical sympathectomy is the somewhat misleading misnomer for the operation performed on the upper thoracic sympathetic chain to obliterate sympathetic innervation to the upper limb. (The inferior cervical ganglion, which may be fused to the first thoracic ganglion as the composite stellate ganglion, is in fact carefully preserved to prevent a Horner's syndrome.) The operation has a declining role in the management of vasospastic disorders, but has proved valuable in the treatment of hyperhidrosis. It is now almost exclusively performed by video-asssisted thoracoscopic surgery (VATS) and a two-port transaxillary approach is usually satisfactory, although a single operating port is also popular. A double-lumen endotracheal tube is required to allow one lung to be deflated (see also Chapter 8). The upper thoracic sympathetic chain is identified as a pale pink structure crossing the necks of the ribs. It is deep to the parietal pleura, which must be incised to isolate it (Figure 4.24). The stellate ganglion normally lies on the neck of the 1st rib and the outflow to the upper limb is below this, from the 2nd to the 5th thoracic ganglia. Cervical sympathectomy consists of division of the sympathetic chain below the neck of the 2nd rib and destruction of the 2nd thoracic ganglion. This is the standard operation for palmar hyperhidrosis. The techniques of individual surgeons vary and there is still controversy as to whether a resection or ablation technique is superior.[8] If repeat surgery is indicated after initial failure of this operation, a T3 sympathectomy is performed and the lower half of the stellate ganglion may also be sacrificed. Any damage to the upper portion of this ganglion will result in a Horner's syndrome. Control of axillary hyperhidrosis requires a T2/T3 sympathectomy, while extension to a T4 sympathectomy may be indicated if repeat surgery is required. Destruction of sympathetic innervation often results in troublesome compensatory sweating.[9] Many surgeons prefer to offer subdermal Botox injections for axillary symptoms. This is a more effective treatment with considerably less risk, but the benefits only last for approximately 6–12 months. Repeat treatments produce a diminishing return over four or five years.

Lumbar sympathectomy

Lumbar sympathectomy has a limited role in increasing skin perfusion and although there is little evidence that it can reverse any of the effects of arterial disease, it occasionally has a role in pain control for patients with no options for revascularisation. Similarly, it has been employed for lower limb vasospastic disorders, accepting a very limited evidence base.

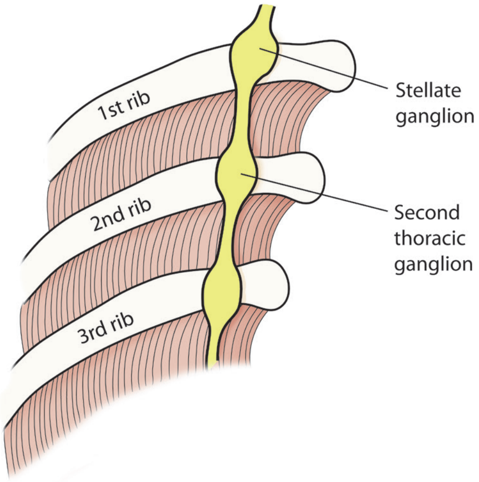


Figure 4.24 *The sympathetic chain lies on the neck of the ribs.*

Lumbar sympathectomy is now most often achieved with a chemical ablation of the sympathetic chain by a paravertebral injection under radiological control. The alternative surgical sympathectomy is performed through a retroperitoneal approach via an oblique loin incision. The sympathetic chain is found lying in the groove between the vertebral bodies and the psoas muscle. On the right it is behind the inferior vena cava (Figure 4.25) and on the left it is beside the left margin of the aorta. The first lumbar ganglion is high up under the crus of the diaphragm and the fourth may be obscured by the common iliac vessels. Removal of the second and third ganglia obliterates the sympathetic innervation distal to the mid thigh and is normally sufficient. If the first lumbar ganglion is destroyed bilaterally, ejaculatory failure will be inevitable.

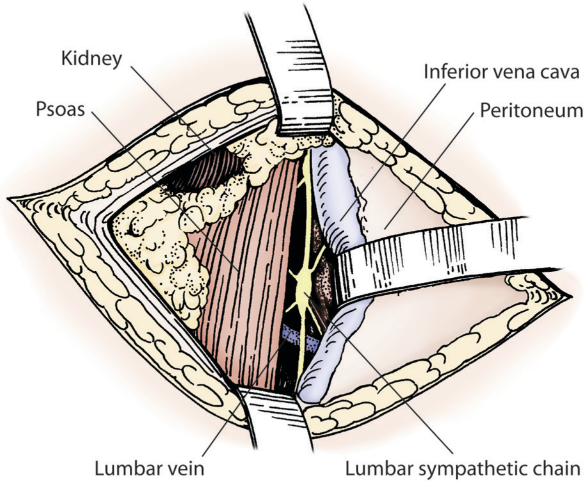


Figure 4.25 *The lumbar sympathetic trunk lies in the groove between the psoas muscle and the vertebral bodies. On the right, the inferior vena cava may overlap it and must be gently retracted.*

Splanchnicectomy

Bilateral thoracoscopic splanchnicectomy has been employed for relief of pain in chronic pancreatitis but only gives sustained long-term relief in a minority of patients.[10] The sympathetic chains are exposed from the level of the T5–T12 ganglia and their splanchnic branches divided.

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5

SURGERY OF BONE AND AMPUTATIONS

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Although skeletal surgery is perceived to be almost exclusively within the province of the orthopaedic surgeon, all surgeons must have an understanding of the principles of surgery on bone. Rib resection and division of the sternum or clavicle may be required for access to intrathoracic structures, and access through bone is required for surgery to the brain and spinal cord. A general surgical operation may include the excision of bone *en bloc*, with the main specimen ranging from the central portion of the hyoid bone with a thyroglossal sinus, to part of the sacrum with an advanced intrapelvic malignancy.

Trauma to bone – and the resulting fractures – do not occur in isolation, and general and orthopaedic surgeons caring jointly for a patient with multiple injuries must understand the challenges in the other specialty. Vascular and orthopaedic surgeons may have to work in parallel to save a limb with an unstable compound fracture and a severed major artery (see Chapter 6). Unstable pelvic ring fractures with massive pelvic haemorrhage and abdominal organ trauma require close interdisciplinary cooperation. Many cranial, sternal and rib fractures are of little significance in themselves and healing will occur without treatment, but they are indicators of major impact and signify the possibility of injury to underlying organs. Conversely, a surgeon caring for a patient with severe intra-abdominal, chest or head injuries must understand the priorities – and principles – of management of the associated orthopaedic trauma.

Amputations in the developed world are most commonly performed for peripheral arterial occlusive disease. These amputations are routinely undertaken by general or vascular surgeons, whereas amputations for trauma are generally the province of the orthopaedic surgeon.

For these reasons, and because many isolated general surgeons may feel the need to offer a limited orthopaedic service, some basic orthopaedic techniques, the principles of stabilisation of fractures and the treatment of osteomyelitis will be discussed in this chapter. However, a true surgical generalist who has the necessary facilities and resources to offer a more comprehensive orthopaedic service will find this chapter lacking in detail, and further orthopaedic training and reading will be essential.[1]

INFECTION IN BONE

Most elective orthopaedic surgery is ‘clean’ surgery in as much as the bone is approached through prepared skin and the risk of contamination from respiratory, urinary or gut organisms is minimal. If infection is introduced into bone, the consequences can be disastrous, especially if foreign material (e.g. an internal fixation device or a prosthesis) is to be left *in situ*. Meticulous aseptic technique is mandatory and, for joint replacement work, a dedicated theatre and additional methods to maintain extra clean air are needed if infective complications are to be avoided. Elective surgery should be postponed if the patient has any septic focus. The surgery is routinely covered with prophylactic antibiotics (see Appendix II), but general methods of preventing the conditions predisposing to infection are equally important. Surgical trauma can be minimised by gentle tissue handling and haematoma formation can be reduced by meticulous haemostasis, with postoperative vacuum drainage when appropriate.

An *open (compound) fracture* is already contaminated and early wound toilet is mandatory to prevent infection becoming established. The risk of infection in compound fractures varies. The fracture may be compound merely because the fractured sharp end of a superficial bone has punctured the skin from within. Alternatively, there may be extensive soft tissue damage from a direct blow from without, which has also carried soil and clothing into the shattered bone and damaged soft tissues. Management of the associated soft tissue and vascular damage is discussed in Chapters 4 and 6.

Osteomyelitis

ACUTE OSTEOMYELITIS

This condition requires urgent treatment with antibiotics, which are most effective when administered intravenously to guarantee high blood levels. Lucency within the bone or a periosteal reaction may be visible on X-ray but the clinical signs usually precede any radiological evidence. The commonest organism is *Staphylococcus aureus* and an appropriate antibiotic for this organism is chosen while results of blood culture and sensitivity are awaited. *Salmonella* infections are common in patients who have sickle cell disease. If there is not a dramatic improvement within 24 hours, trapped pus must be suspected and drained. With late presentation pus may already have formed, and delaying surgical drainage further for a trial of antibiotics is contraindicated. In the developed world osteomyelitis is no longer common; when it does occur it usually presents early, settles on antibiotic therapy and surgical drainage is seldom required.

The increased pressure from the inflammatory swelling and trapped pus compromises bone perfusion. In addition, subperiosteal pus strips the periosteum, with the nutrient arteries, off the underlying bony cortex. Thus, untreated osteomyelitis rapidly progresses to ischaemic necrosis of bone. A state of chronic osteomyelitis is then established, which can last a lifetime. In the child, damage to the adjacent growth plate may cause long-term sequelae and in the very young, metaphyseal osteomyelitis may spread into a neighbouring joint with resultant septic arthritis.

Surgical drainage consists of an incision down to bone at the level of maximum tenderness and swelling. Any subperiosteal abscess is evacuated and several drill holes are then made through the cortex of the metaphysis to allow the release of an intraosseous abscess. Pus should be saved to allow identification of the infecting organism. The skin incision may be closed over a vacuum drain, but the wound should remain visible for inspection. A plaster cast should be applied if there is any danger of a pathological fracture developing, but a window must be cut for wound inspection. The situation should also be monitored by radiological imaging and inflammatory markers.

CHRONIC OSTEOMYELITIS

This condition is characterised by chronic bony sepsis associated with necrotic bone. The dead bone forms a ‘foreign body’ and any organisms that persist within it are safe from high blood levels of antibiotics. Eradication of infection and, finally, healing are only possible after the removal of any sequestra of dead bone, the extent of which should be investigated by preoperative X-rays. At operation, abscess cavities within the bone are deroofed and any sequestra, which are recognised by their white appearance, are lifted out. This is usually easy if all overhanging bone has been removed and the sequestra are lying free within the pus. Involucrum (new bone) laid down around a sequestrum may make the surgery more difficult. All the dead bone must be removed and, if a sequestrum is encased within involucrum, much of this healthy new bone may have to be sacrificed. However, if the need for major bony reconstruction is to be avoided, retention of some involucrum may be essential to maintain the integrity of the bone. The dead space can then be filled with viable soft tissue such as a muscle flap (see Chapter 4).

SURGERY OF BONE: BASIC SURGICAL TECHNIQUES

Most surgery on soft tissue consists of dissection, following an anatomical plane, and the approximation of tissues with sutures. The skills required for surgery on bone are very different. Bone cutters will cut a thin bone and small pieces of bone can be removed with bone nibblers. Larger bones may be cut with a classical hand saw, while the soft tissues are retracted so that they are not damaged. Retraction is difficult in some circumstances. A Gigli saw is useful where access is difficult (Figure 5.1) and a combination of techniques may solve a difficult problem. Hand-held electric saws with an oscillating circular blade have overcome many of the problems, both of access and of potential soft tissue injury. Bone

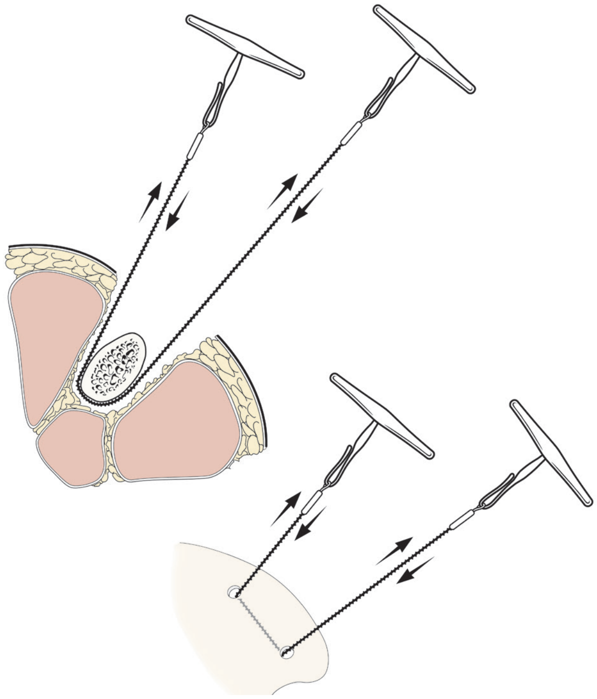

Figure 5.1 *Access to bone with a classical saw may be obstructed by soft tissue. A Gigli saw overcomes this problem. It can also be used to divide a flat bone (e.g. ilium or cranium) between two drill holes. Modern electric circular saws are now preferred in most situations.*

may also be cut using an osteotome and hammer. Drill holes in bone can be made by a hand-held brace and bit or, more commonly now, by an electric drill. Drills have many further uses in the surgery of bone. They are used to introduce Kirschner wires and guide wires and the pins for skeletal traction. They may be used to drill a hole through the bone for a screw or to make a shallow hole that can be gripped by the tongs used for skull traction. A hole may also be required for a ligature for soft tissue reattachment or for a wire to fix two pieces of bone.

Bone cannot be sutured directly, and alternative methods of attaching soft tissue to bone have been devised (see Chapter 4). If bone-to-bone apposition requires stabilisation, this may be achieved by placing a screw (Figure 5.2a), an intramedullary rod (see Figure 5.11) or a Kirschner wire (see Figure 5.6) from one piece of bone into the other. This may require open apposition of bone ends or, in some techniques, the apposition can be achieved by a closed method and the wire or pin inserted percutaneously at a distance from the fracture site. Bone can also be wired together around pins inserted into the bone (see Figure 5.7) or a plate may be laid over the fracture and the plate fixed to both segments with screws (Figure 5.2b). A bone staple is another method of fixation (see Figure 5.4a). An alternative to fixation within the tissues is a rigid external 'fixator' outside the limb, to which are fixed pins that have been drilled into the bony fragments (see Figure 5.3). Compression of the fracture increases stability and hastens healing.

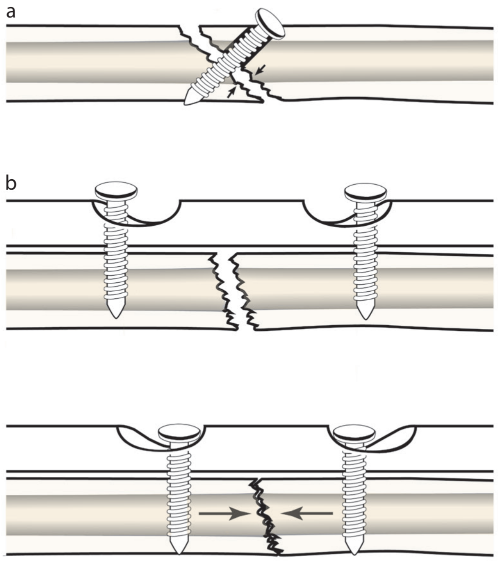

Figure 5.2 *(a) Screw fixation across a fracture. The screw should cross the fracture at right angles. 'Overdrilling' of the proximal cortex results in compression of the fracture as the thread 'bites' in the distal cortex. (b) Internal fixation of a fracture with a plate must hold the bone ends in apposition. Additional compression of the fracture can be achieved by a variety of techniques. The simplest is a plate with obliquely bevelled oval screw holes. As the sloping shoulder of the screw is tightened against the plate, the small lateral movement compresses the fracture.*

BONE HEALING IN FRACTURES AND ELECTIVE ORTHOPAEDIC SURGERY

Bone ends in apposition normally heal. Initially, there is a haematoma between the ends and fibroblasts and capillary loops grow into the haematoma. As the first bone is laid down the *callus* between the bone ends becomes visible on X-ray at around 4–6 weeks. Organisation within the callus results in increasing strength; a healing bone typically recovers approximately 75 per cent of its strength at 3 months. Finally, remodelling of the bone occurs, which compensates for minor malalignment of the fracture. This process occurs spontaneously after most fractures, and many heal satisfactorily without any intervention. Skull, rib, minor vertebral, pubic, clavicular, humeral, metacarpal and digital fractures are all examples. Some form of splintage may reduce pain and maintain alignment, but is not essential for healing.

MALUNION

If a grossly displaced fracture is allowed to heal without reduction into a satisfactory alignment, the fracture is described as 'malunited'. Compensatory remodelling will be insufficient to restore normal anatomy. The deformity may be from overlap of bone ends and subsequent limb shortening, from angulation or from rotation at the fracture site. Even after an initial satisfactory reduction, significant malalignment recurs if the forces across the fracture displace the alignment of the fragments. In these situations, stabilisation of the fracture site is essential for satisfactory healing. In some instances traction is suitable, while in other fractures either external or internal fixation of the fracture may be more appropriate.

Fractures into a joint form a subgroup in which even minor degrees of malalignment are unacceptable. Accurate apposition of articular surfaces is essential to reduce post-traumatic arthritic changes in the joint. Internal fixation is usually preferred to allow early movement, thus minimising stiffness.

NON-UNION

A non-united fracture is one in which no rigid bony bridge has formed between the bone ends within 3 to 6 months. Instead, there is a bridge of fibrous tissue. A few fractures are notorious for problems with non-union. The distal tibia, the scaphoid and the femoral neck are probably the three most common, and in the latter two cases the underlying problem is, at least in part, a poor blood supply to one fragment of bone. Rigid immobilisation of the fracture site improves the chances of satisfactory healing.

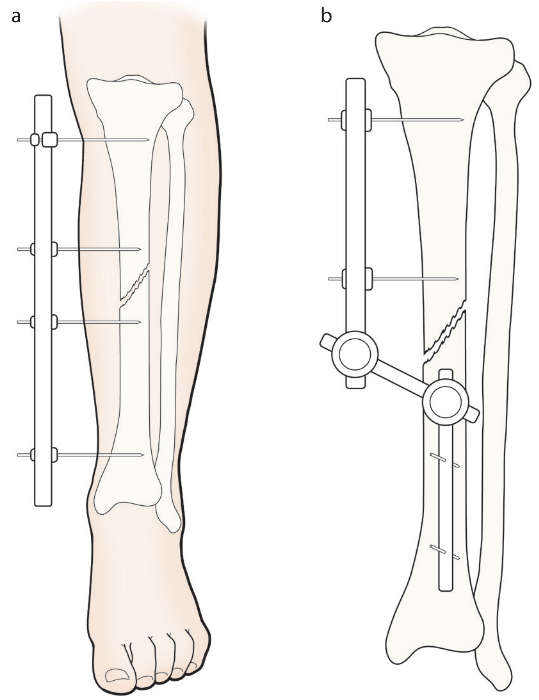

Figure 5.3 *(a) A simple unilateral uniplanar external fixation system where the pins have been fixed directly to a single connecting rod. (b) Two pins with a connecting rod form a partial frame for each fragment. The two partial frames are joined by an additional rod to allow adjustment of the reduction before final tightening of the fixation. This is more versatile but can reduce the stability of the fixation.*

Fracture immobilisation

EXTERNAL SPLINTAGE

If a fracture requires immobilisation, the simplest method is an *external plaster of Paris splint*, after reduction of the fracture if necessary.[2] In order to immobilise the fracture of the shaft of a long bone, the plaster must extend to include the joints both proximal and distal to the fracture. However, fractures in the vicinity of a joint can normally be satisfactorily immobilised by a cast that includes that joint, but which stops short of the second joint. For example, a fracture of the tibial shaft requires a plaster of Paris splint that includes the knee and ankle, whereas a malleolar fracture only needs a below-knee cast and a tibial plateau fracture requires a plaster cylinder extending from the upper thigh to above the ankle. The disadvantages of an external rigid cast are immediately apparent. One or two joints are held immobilised for 6–12 weeks, with resultant stiffness (see Chapter 4), and the plaster may be very heavy and make nursing difficult. (This is a particular problem when a hip spica is applied for a fractured femur.) The injured limb is hidden from view and if there is an associated soft tissue injury that needs attention, windows have to be cut in the plaster. In addition, an external plaster cannot hold accurate bone apposition, as is ideal for an intra-articular fracture.

OPEN FIXATION

Open fixation of a fracture overcomes many of these problems.[3] Fracture apposition, which is so important in an intra-articular fracture, can be more accurate. The healing phase is generally more efficient and precise, without the need to lay down a large mass of callus followed by remodelling. The fractured bone is stabilised but the joints are kept mobile, and soft tissue wounds are more accessible. There is, however, the disadvantage of a skin wound and the cosmetic implications of the subsequent scar are distressing to some patients. Healing of the wound, which is often through tissues that are already traumatised, may be troublesome and there is also the possibility of introducing infection. Compound fractures may be grossly contaminated and this has led to concern regarding the increased risk of infection with internal fixation, but this risk is mitigated by the improved stabilisation of the fracture, provided there has been adequate debridement. However, in the presence of contamination, external fixation may be the simpler and safer option. Later removal of the plate or screw may be indicated, and this will require a second operation. (If a plate is left *in situ*, the natural stress lines within the bone are distorted and it is at increased risk of further fracture, usually at the ends of the plate.) In addition, a bone is at increased risk of fracture for a period after the plate is removed. Internal fixation also has the potential for increasing the chance of non-union by holding the bone ends apart. Most plates and screws are now designed so that they compress the fracture to reduce this problem (see Figures 5.2a, b).

If a pathological fracture occurs through a bony metastasis, healing will not occur spontaneously. Local radiotherapy may allow the fracture to heal and is often all that is required in, for example, a fracture of the pubic ramus or vertebral body. If, however, the fracture itself requires prolonged immobilisation or traction, additional open fixation (usually with an intramedullary rod) will improve the quality of the patient's remaining life.

EXTERNAL FIXATION

External fixation is a versatile technique for stabilising a fracture and is particularly useful in open fractures with severe soft tissue injuries. Fixation is not as rigid as with open fixation but it is adequate for healing by callus formation. Less skill is required than for open fixation but, more importantly, the risk of infection is less and its use causes minimal additional surgical soft tissue injury. External fixation can also be used as a temporary method to stabilise a fracture prior to internal fixation and for the secondary correction of a deformity.

To achieve maximum stability at least two pins have to be inserted into each main fragment and they should be placed as wide apart as possible. If the soft tissue situation allows, one pin is inserted into each fragment as close to the fracture as possible, but these should not enter the fracture haematoma and should also avoid any future surgical field if delayed open fixation is planned. All the pins can be connected by a single rod, which should be placed as close as possible to the bone to increase stability (Figure 5.3a). This is the simplest arrangement and uses the least equipment, but has the disadvantage that the pins must all be in line and the reduction cannot be altered. Alternatively, each pair of pins is connected to a separate rod. This produces a partial frame for each main fragment. The rods may then be fixed directly to each other with a clamp, but if they are connected by an additional rod, this creates a more versatile frame, which allows reduction in all planes (Figure 5.3b). Once the desired reduction is achieved, the clamps are tightened and the system is stable.

Elective surgery on bone

Orthopaedic surgeons use the principles of healing and stabilisation of fractures in some simple elective procedures:

- *Osteotomy*. A bone may be cut and realigned to correct a deformity. Three variants are shown in Figure 5.4.
- *Arthrodesis*. If the articular cartilage of a joint is destroyed by inflammation, spontaneous bony union (ankylosis) may occur. This can produce a rigid, but stable and pain-free, joint. It is therefore most important that the joint is immobilised in the optimum position

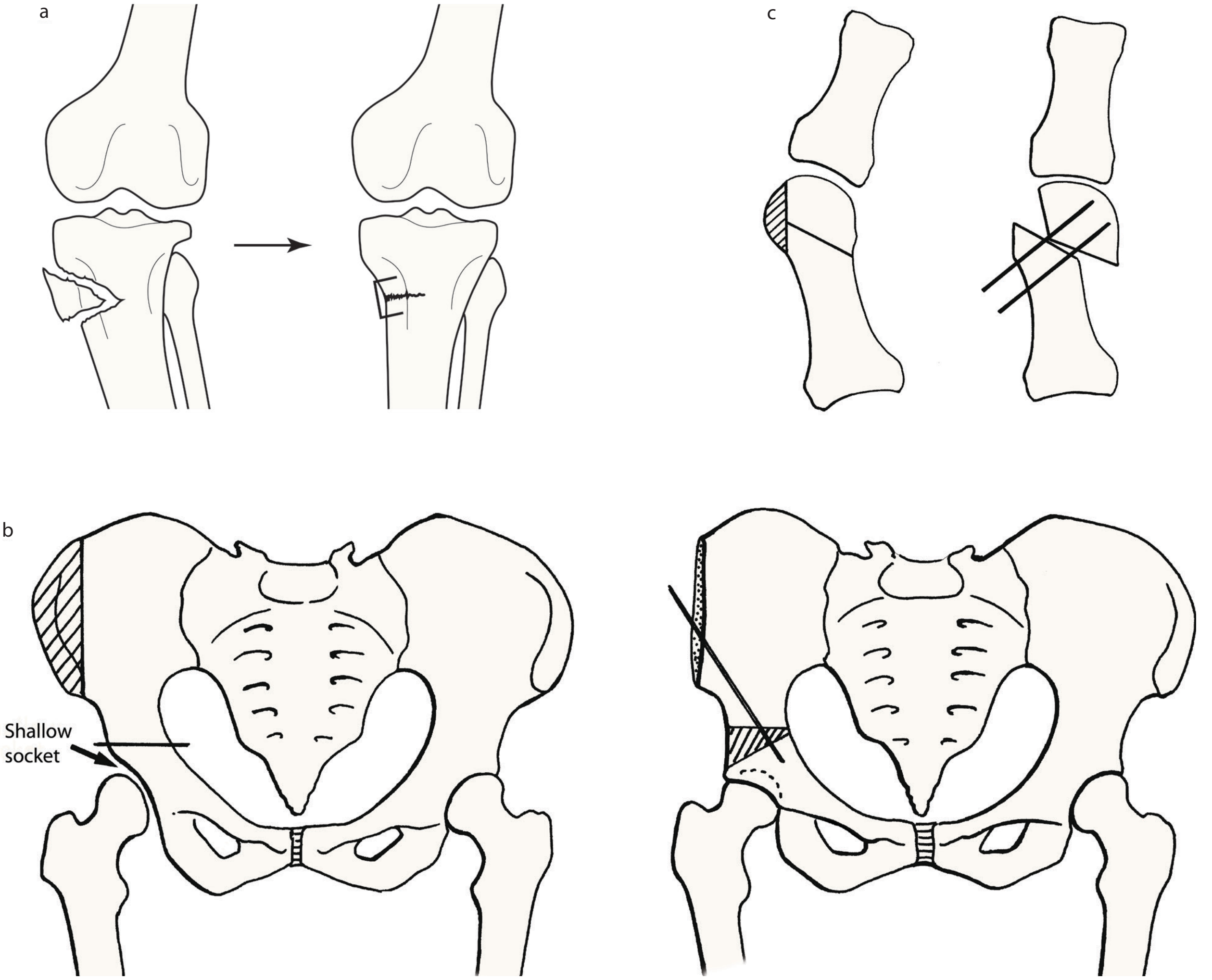

Figure 5.4 *Osteotomy. (a) Osteotomy of the proximal tibia to correct a varus deformity. A wedge of bone has been excised and the new position held with a bone staple. (b) An innominate osteotomy, which alters the angle of the shallow acetabulum of a congenital dislocated hip. The wedge opening is packed with cancellous bone chips. (c) Wilson's osteotomy for hallux valgus.*

for function (see Chapter 4). A similar situation can be achieved surgically by arthrodesis. The articular cartilage and underlying cortical bone are excised and the two denuded bone ends are then fixed in apposition (see Figure 5.14). The addition of a bone graft across the joint is also sometimes employed.

- *Excision arthroplasty*. If fractured bone ends are not in apposition, a non-union or loose fibrous union may result. This principle is used in excision arthroplasty. It gives good results in non-weight-bearing joints such as an interphalangeal joint, where it can be useful for a claw toe deformity (Figure 5.5). Despite the fact that the hip is a major weight-bearing joint, an excision arthroplasty (Girdlestone's operation) is a valuable operation for a severely damaged hip if a joint replacement is not possible (see Figure 5.12).

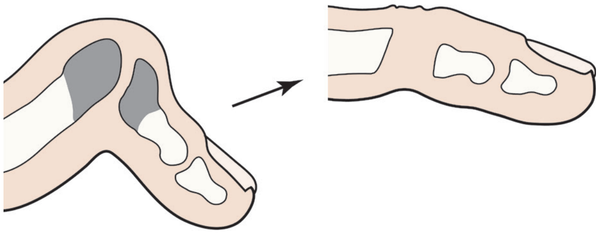

Figure 5.5 *Excision arthroplasty is a satisfactory operation for a painful non-weight-bearing joint.*

JOINT REPLACEMENTS

Artificial joint replacements (arthroplasties) are now possible for many damaged joints. The fixation of the prosthesis to the bone in order to maintain a long-term rigid bond was one of the most difficult early challenges for this surgery. Postoperative infection remains a concern. This specialist orthopaedic surgery cannot be covered in a general surgical operative text.

BONE GRAFTING

Bone grafting may be performed with either cancellous or cortical bone. Bone grafts do not survive, but act as a scaffold for the formation of new bone. Bone allografts, if available, are an acceptable alternative to the patient's own bone; both are absorbed and replaced and therefore immunological rejection is not an issue, but they require sterilisation to minimise the risk of cross infection and are mechanically inferior to an autograft. Small grafts are more rapidly replaced than large grafts, and the least possible amount of bone should be used. Cancellous bone is more easily vascularised and offers less volume of bone to be reabsorbed. It is therefore preferred unless there is an overriding mechanical requirement that demands the denser, stronger cortical bone. A cortical bone graft can be used as a 'strut', or as a stabilising 'pin' or 'plate'. The fibula or a portion of rib makes an ideal strut or pin, and a rectangle of cortical bone can be cut from the tibia and used as an on-lay plate. A cortical strut of bone can be used in reconstructive surgery; for example, to bridge a mandibular defect after a radical excision for cancer of the floor of the mouth. The iliac crest is the favoured site for harvesting the more useful cancellous bone. Bone grafting techniques are of value in arthrodesis of some joints, and may also be used across a fracture that has formed an unstable fibrous union. They are, however, used less frequently following the development of more sophisticated internal fixation devices.

A general surgeon whose practice also includes orthopaedics may wish to undertake some of the simpler elective orthopaedic procedures. Unfortunately, space does not permit their inclusion in a general surgical operative textbook, and orthopaedic texts should be consulted. However, individual fractures and the surgical approaches to the long bones are discussed briefly, along with a few selected orthopaedic procedures. It is hoped that this, combined with the general principles outlined above, may be of some value to general surgeons who find themselves forced by circumstance to stray into orthopaedic territory.

SURGICAL EXPOSURE AND THE MANAGEMENT OF SPECIFIC FRACTURES

Cranial bones

Fractures of the skull and access to the brain are discussed in Chapter 9.

Faciomaxillary skeleton

Fractures of the zygoma, maxilla and mandible are discussed in Chapter 11.

Vertebral column

Minor stable fractures may need little treatment other than pain relief. In unstable fractures the major concern is protection of the spinal cord, and this can often be achieved by external support with special beds or plaster shells or, in the case of cervical fractures, with traction. Operative fixation has some advantages in allowing early mobilisation, but these are not operations for a surgeon unfamiliar in this territory, as the approaches are technically demanding and there is potential for secondary spinal cord damage. Conservative management will often be the safer option for a general surgeon.

The position of an unstable cervical spine fracture can be maintained in cervical traction, which can also be used for the reduction of a cervical facet joint dislocation. Traction is attached to skull callipers, which grip the outer table of the skull, and the patient is nursed on his or her back in a 10 degree head-up tilt. The patient's weight in this position provides the counter-traction. Alternatively, a four-point skull fixation to an external halo attached to a body jacket will allow the patient to be ambulant. When there is an unstable cervical fracture, the drill holes for the pins of the skull callipers are safer established under local, rather than general, anaesthesia. The anaesthetic agent must be infiltrated deeply to include the pericranium. A 2- to 3-cm incision is made a few centimetres above the external auditory meatus on both sides. The pericranium is incised and a small area of bone bared. The outer table of the skull is then drilled, with the guard preventing the drill from penetrating too deeply.

Surgery to decompress a spinal cord, perhaps threatened by a disc prolapse or an abscess, is an emergency, but one that should be transferred if at all possible to specialist services. Occasionally, an isolated surgeon may have to proceed and, if pus causing the compression can be drained, there is a good chance of success. This is discussed further in Chapter 9.

Elective surgery of the vertebral column is highly specialised and is unsuitable territory for the occasional operator in this field.

Ribs, sternum, scapula and clavicle

Surgical stabilisation of these fractures is seldom required. The injuries are important, not in terms of their damage to the skeletal system but as an indicator of likely damage to underlying organs. A fractured sternum may be associated with contusion to the heart. A severely displaced fracture or dislocation of the clavicle can be associated with trauma to the major vessels of the superior mediastinum or with compression of the trachea. A fractured rib may tear an intercostal vessel or the underlying lung, with subsequent haemothorax or pneumothorax, and there will also inevitably be underlying lung contusion. Multiple rib fractures may cause mechanical difficulties with breathing. Management, however, is mainly of the underlying organ trauma and is discussed further in Chapter 8.

Clavicular fractures, even when displaced, seldom require formal fixation. However, in a severe avulsion-type upper limb injury there may be a partial brachial plexus injury and associated concern over major vessel damage in a severely injured patient. A fractured clavicle may be the only apparent skeletal injury in the region, even though there is often significant tearing of scapular musculature and the whole shoulder girdle is 'floating'. These patients may have severe head and chest injuries, and it is easy to ignore an apparently minor clavicular fracture. However, in this situation, internal fixation of the clavicle is indicated to stabilise the shoulder girdle. A simple plate across the fracture site is suitable. Sternal division, rib resection and clavicular division are all employed to gain access to the heart, great vessels and lungs. These techniques are discussed in Chapter 8.

Humerus

Many humeral neck and shaft fractures heal with minimal intervention. External stabilisation with a plaster cast is unsatisfactory and if rigid fixation is deemed necessary, plate fixation is the usual choice. For example, rigid fixation of any fracture is normally mandatory in circumstances where there has been associated damage, and subsequent repair, to an artery or nerve. The radial nerve is occasionally torn by a mid-shaft fracture and if division is suspected, surgical exploration is indicated (see Chapter 4).

Supracondylar fractures are common in childhood. The elbow, with the distal humoral fragment, is displaced posteriorly; this causes the brachial artery to be stretched over the deformity and to be endangered by the sharp bone ends. If the artery is undamaged, closed reduction of the fracture usually restores the radial pulse, and the elbow is then held in acute flexion in a high collar and cuff sling. If the pulse is again lost, it may be simply due to compression from swelling, and straightening the elbow may restore it. The fracture can then be managed temporarily by skin traction, while resting the limb on a splint until any swelling has subsided. If concern remains over the artery, particularly if hand perfusion is poor, the artery should be explored as described in Chapter 6.[4] The surgeon should also be alert for a developing compartment syndrome (see Chapter 4), which is a not uncommon complication of this injury. Increasing pain, exacerbated by passive extension of the fingers, is an indication for fasciotomy of the flexor compartment of the forearm. Unstable supracondylar fractures are best treated with crossed Kirschner wires (Figure 5.6). Fractures of the medial and lateral epicondyle can also be managed in this fashion. The wire is drilled into the distal fragment, the fracture reduced and the wire advanced across the fracture into the main portion of the humerus. Care must be taken to protect the ulnar nerve on the medial side of the elbow.

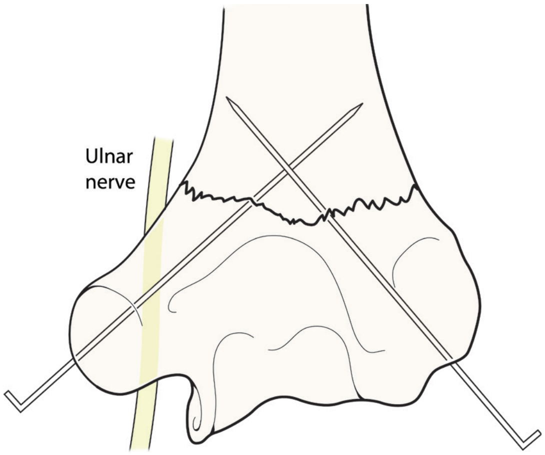

Figure 5.6 *The reduction of an unstable supracondylar fracture may be held with Kirschner wires.*

The shaft of the humerus can be approached anteriorly or posteriorly. The anterior approach to the proximal shaft is between the deltoid and pectoralis major muscles, and a cephalad extension of this incision is used for anterior access to the shoulder joint. More distally, the anterior approach is through an incision placed just lateral to the lateral border of biceps. The cephalic vein and biceps are retracted medially to expose brachialis, which is then split in the direction of its fibres. The posterior approach to the shaft of the humerus is between the long and lateral heads of triceps. The radial nerve must be identified and preserved. The humeral condyles are superficial and access is straightforward through a medial, lateral or posterior longitudinal incision, depending on the position of the fracture. The ulnar nerve, lying posteriorly on the medial side, must be safeguarded.

Radius and ulna

Olecranon fractures cross an articular surface and the triceps muscle pulls the fragments apart. Open fixation is therefore indicated and tension wiring may be employed. Two Kirschner wires are introduced across the reduced fracture, via a posterior approach. A drill hole in the ulna allows a wire figure-of-eight to be formed around the Kirschner wires and through the hole and then tightened (Figure 5.7). Radial head fractures may be treated conservatively but if comminuted and displaced, the radial head is better excised. A dislocated radial head requires surgery for accurate reduction and repair of the annular ligament. In both these situations the radial head can be approached posterolaterally, but care must be taken to avoid damage to the posterior interosseous (motor) branch of the radial nerve. The associated ulnar fracture then requires open fixation.

Mid-shaft combined radial and ulnar fractures cannot be held satisfactorily by external splintage. Open fixation with plates is performed through two separate incisions. The ulna is easily approached posteriorly, where it can be felt subcutaneously. The radius is approached anteriorly by an incision along the medial border of brachioradialis. The muscle is then retracted laterally, together with extensor carpi radialis longus and brevis. The radial nerve is on the deep surface of brachioradialis and is displaced laterally. The radial vessels are retracted medially with the anterior muscles. Distal radial fractures seldom require operative intervention. If reduction cannot be maintained, a Kirschner wire across the fracture site may be helpful.

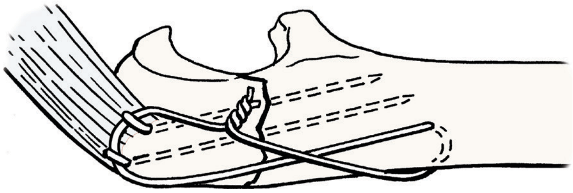

Figure 5.7 *A hole is drilled in the ulna and Kirschner wires are inserted across the fracture from the olecranon fragment. Tension wiring compresses and further stabilises the fracture.*

Hand

Most fractures of the hand heal without intervention. A scaphoid fracture requires rigid immobilisation, but closed treatment is usually satisfactory. Metacarpal and phalangeal fractures often require little treatment. Displaced unstable fractures may be held with Kirschner wires, and this is more often indicated in fractures of the thumb and first metacarpal. Compound fractures associated with tendon and digital vessel trauma require very careful assessment, as early amputation may be the best option. Preservation of function in a severely damaged hand by splintage and physiotherapy is most important (see Chapter 4).

Pelvis

Many minor fractures of the pubic rami or blade of the ilium, without disruption to the pelvic ring, require no intervention. Displaced anterior fractures may be associated with bladder or urethral injuries (see Chapters 25 and 26). An unstable anterior fracture can be stabilised by using a simple plate. Fractures through the acetabulum often lead to later arthritis of the hip. They may be treated with skeletal traction, as discussed below, but more accurate open reduction of the bone and internal fixation allow earlier mobilisation and may give a better final outcome. These injuries are sometimes associated with pelvic organ or vascular damage, and cooperation in management is needed between specialist surgeons.

Major *pelvic ring disruption* may be a life-threatening injury. It most often takes the form of an anterior fracture, which opens on a 'hinge' formed by a disrupted sacroiliac joint, or a fracture in the vicinity of this joint. Major force has caused this injury and there may also be damage to the bladder, urethra and rectum. Open fractures carry a significantly worse prognosis because of contamination, and a defunctioning colostomy should be performed if the rectum is perforated. The initial life-threatening problem, however, is haemorrhage from torn pelvic veins.[5] A retroperitoneal pelvic haematoma further opens the pelvic ring and the increasing distortion of normal anatomy results in additional venous disruption. The patient may also have severe injuries in the upper abdomen and chest, and the correct decisions over surgical priorities are essential for a successful outcome. The pelvis must be stabilised urgently in the accident department to prevent further opening of the pelvic ring with subsequent venous tearing (Figure 5.8). Stabilisation also compresses the haematoma and reduces venous haemorrhage. Laparotomy, unless mandatory for some other intra-abdominal injury, is not indicated as the first line in management. If external fixation fails to control

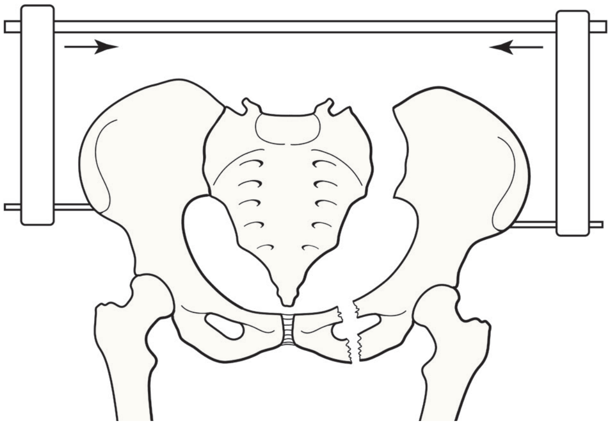

Figure 5.8 *External stabilisation of a pelvic fracture is the most effective manoeuvre to reduce venous bleeding from torn posterior pelvic veins. The lateral pins are inserted percutaneously into the lateral surface of the ilium and the two side arms pulled inwards to close the opened pelvic ring. Rotation of the device allows access for a laparotomy.*

haemorrhage – and especially if additional arterial bleeding is suspected – early angiographic embolisation of the bleeding vessels is now considered the optimal treatment. If this is unsuccessful – or if interventional radiology is unavailable – emergency laparotomy and pelvic packing is the next option. Exploration of the haematoma to indentify and secure relatively inaccessible torn vessels within a haematoma is seldom practical. Any tamponade effect has been lost and venous bleeding increases, often from veins that have torn where they emerge from the ilium and are not amenable to surgical suture. The pelvis should be packed. If this also fails to control haemorrhage, bilateral internal iliac artery ligation may be successful. Unilateral ligation of the internal iliac artery or vein on the affected side is less effective than selective embolisation, as the ligation is some distance from the bleeding point and the extensive cross-circulation within the pelvis maintains blood flow through the damaged vessels.

ILIAC BONE GRAFTS

Cancellous bone may be harvested from the iliac crest for use as a bone graft. An incision is made parallel to, and just below, the crest extending from just posterior to the anterior superior spine posteriorly as far as required. Extending the incision further anteriorly places the lateral cutaneous nerve of the thigh at risk. The lateral surface of the ilium is exposed subperiosteally and the crest with its attached muscles is detached with an osteotome and reflected medially, care being taken to leave the anterior spine undisturbed. The medial aspect of the ilium is then exposed. Thin slivers of cancellous bone are cut from the exposed margin of the ilium, with five or six slivers, each 6–10 cm in length, being sufficient for most purposes. The detached crest is then sutured back onto the periosteum and muscles on the outer face of the ilium.

Femur and hip joint

Intertrochanteric fractures and fractures of the femoral neck are mainly fractures of the elderly. Although the former may heal with traction, they are better treated by internal fixation. Femoral neck fractures heal poorly. They require rigid intramedullary fixation across the fracture line or prosthetic replacement of the femoral head (hemiarthroplasty). Stabilisation must be of sufficient strength to allow immediate weight bearing and avoid prolonged immobilisation of an elderly patient (Figure 5.9). Treatment of these common fractures involves skills that the true surgical generalist may wish to acquire if his or her practice is to include orthopaedics. The operations are not included here because unless a general surgeon has planned a relatively comprehensive orthopaedic service, he or she will not have the equipment and skills necessary to undertake these operations. In addition, the technique varies with the equipment available. Operative management of congenital dislocation of the hip and surgery for hip replacement are excluded for the same reasons.

Fractures of the femoral shaft may be treated with a plaster of Paris cast, but the method is seldom used except in childhood. The plaster is very heavy as it extends both up around the pelvis and down to below the knee. It does, however, allow a child to be nursed at home. Accurate apposition and rigid immobilisation are not essential for the healing of these fractures, but malrotation must be avoided. A small amount of angulation, overlap and shortening can be accepted, particularly in children, where minor deformities will remodel. The simplest form of treatment is therefore traction, with the

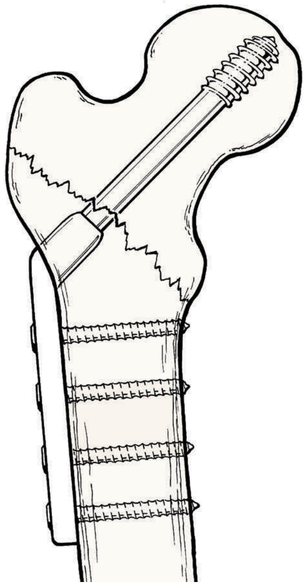

Figure 5.9 *Internal fixation of a hip fracture should be sufficiently robust to allow early weight bearing. Intraoperative X-rays are necessary for accurate placement of the pin or screw along the femoral neck into the proximal fragment.*

limb supported on a Thomas splint (Figure 5.10a). The alternative 'gallows' traction is suitable for a baby or toddler (Figure 5.10b). Skin traction is very satisfactory in children as the skin is relatively strong, the traction required is less and the duration of traction required is approximately half that required for an adult. Skeletal traction is usually preferred in an adult and, with balanced traction, allows flexion of the knee to maintain the range of movement. A Steinmann or Denham pin is introduced, under general or local anaesthesia, through the upper tibia just posterior to the tibial tubercle. The weight required is around 10 kg in an adult. Alternatively, intramedullary nailing of the fracture can be used to avoid the long period in traction (Figure 5.11).

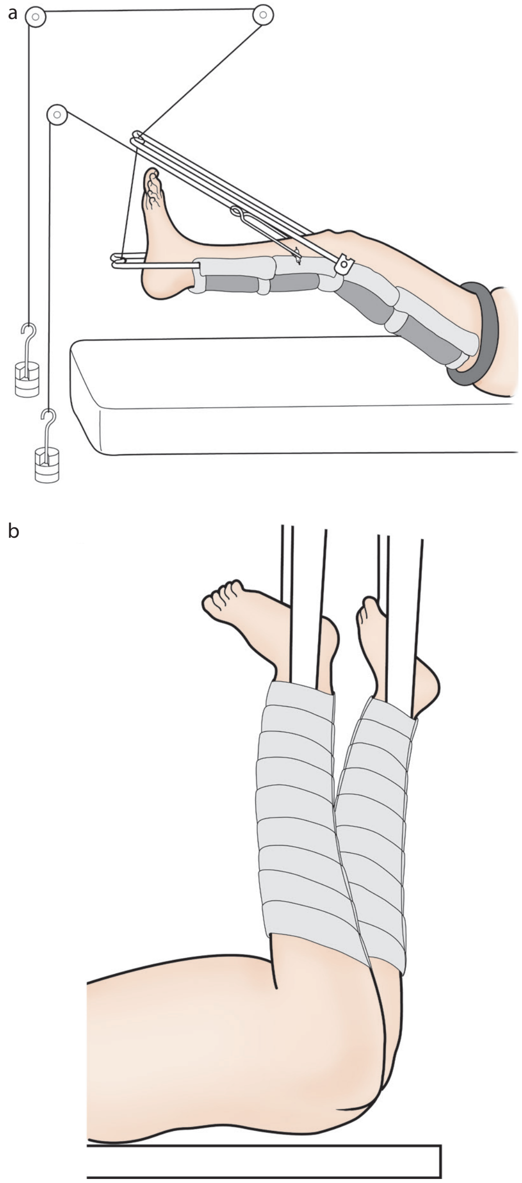

Figure 5.10 *Accurate apposition and rigid immobilisation are not essential for femoral shaft fractures, but traction is required to prevent overlap. (a) Skeletal traction in a Thomas's splint. (b) 'Gallows' skin traction in a baby.*

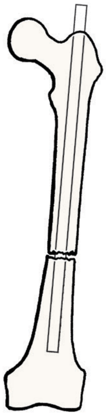

Figure 5.11 *An intramedullary nail* in situ *after an open insertion. It is introduced into the proximal medulla from the fracture site and driven up through the trochanter until it can be introduced into the distal medulla. It is then driven back down to cross the fracture site. More sophisticated closed locked intramedullary nails are now widely used.*

Fractures of the femoral condyles and supracondylar fractures are often better treated with a pin to stabilise the reduction. The possibility of associated popliteal vessel damage must be considered.

The upper femoral shaft is most satisfactorily approached through a lateral incision. The vertical skin incision is continued through tensor fascia lata and then deepened to bone at the posterior border of vastus lateralis. Distally, the femoral shaft is more easily approached anterolaterally between vastus lateralis and rectus femoris.

The optimal treatment of a severely damaged hip joint is a prosthetic replacement, and this is now one of the commonest elective orthopaedic operations in the developed world. Many patients are elderly and the commonest underlying pathology is osteoarthritis. In areas of the world with a poor standard of living and limited health facilities, severely damaged hip joints are common and the patients are often young. The original underlying pathology may be a tuberculous or pyogenic arthritis or a premature osteoarthritis in a joint damaged by untreated trauma. Prosthetic hip replacement is often unavailable to these patients, but a *Girdlestone excision arthroplasty* can restore a pain-free weight-bearing limb with a good range of hip movement. No specialist equipment or skills are needed and, as it may be of value to the isolated generalist, this now almost historic operation is described.

The patient is placed on his or her side. The incision is from the posterior superior iliac spine, over the greater trochanter and then distally in line with the femur. Gluteus maximus is divided in line with the skin incision, exposing the short rotator muscles of the hip joint. Figure 5.12 shows the portion of bone that is excised. Postoperatively, traction for 4–6 weeks allows firm scarring and prevents flexion deformity, telescoping and limb shortening.

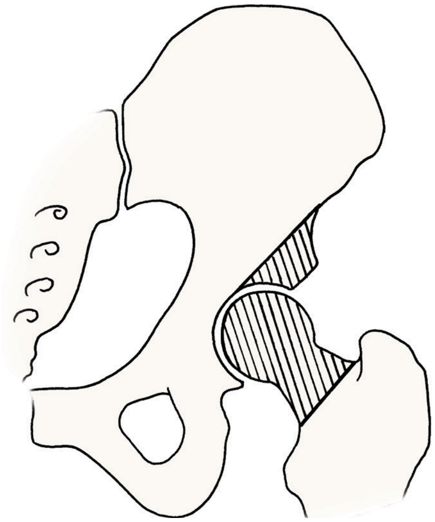

Figure 5.12 *Extent of the bone resection in a Girdlestone pseudarthrosis. This old operation still has a role when a joint replacement is not possible.*

Tibia and fibula: the knee and ankle joint

The possibility of damage to the popliteal vessels must be considered in any severe skeletal injury around the knee and is a particular risk in knee dislocation. Angiography should be employed if there is any concern over distal pulses, and if this does not exclude arterial injury, the vessel should be explored. The surgeon must remember that an intimal tear in an intact artery can progress to a thrombotic occlusion, which can easily be overlooked in a patient whose limb is encased in plaster of Paris (see Chapter 6). Fractures of the tibial plateau that cross the articular surface of the knee joint require accurate reduction to reduce the risk of later osteoarthritic changes. The reduction often has to be held with a pin. Small bony fragments separated from the upper tibia should alert the surgeon to a possible avulsed ligament. A patellar fracture that is not reduced will cause underlying arthritis. The reduction must then be held by a screw or tension wiring, but if comminuted, the patella may be better excised.

Tibial shaft fractures can often be treated satisfactorily by closed reduction and immobilisation in a full-length plaster of Paris cast. Open fixation with a plate (see Figure 5.2b) may be preferred, but a plate that does not compress the fracture site – or which introduces infection – will cause major problems. Severe injuries, with associated vascular and soft tissue damage, require interdisciplinary cooperation to save the limb (see Chapters 4 and 6). Restoration of blood supply is crucial but the vascular surgeon requires limb stability to proceed with fine vascular anastomoses. Rigid external fixation is ideal in this situation (see Figure 5.3).

Fibular fractures are of little significance except where they compromise the alignment or stability of the ankle joint. Fractures of the medial and lateral malleoli are important if there is disruption of the ankle mortise. Minor fractures may be reduced and held in plaster of Paris. Unstable displaced fractures should be stabilised by internal fixation (Figure 5.13).

A patient with an unstable knee may benefit from reconstructive ligament surgery, while one with a painful arthritic knee may benefit from a joint replacement. These are both specialist orthopaedic operations. *Arthrodesis* of a knee can give a sound weight-bearing limb and may still have a place when a joint replacement is not available (Figure 5.14). Through an anterior transverse incision, the knee joint is entered by division of the patella tendon. The knee is flexed to expose the cruciate and collateral ligaments, which are divided. The joint surfaces are then resected and the cancellous bone ends held in compression apposition as shown. Correct alignment and 15 degrees of flexion are important for good function.

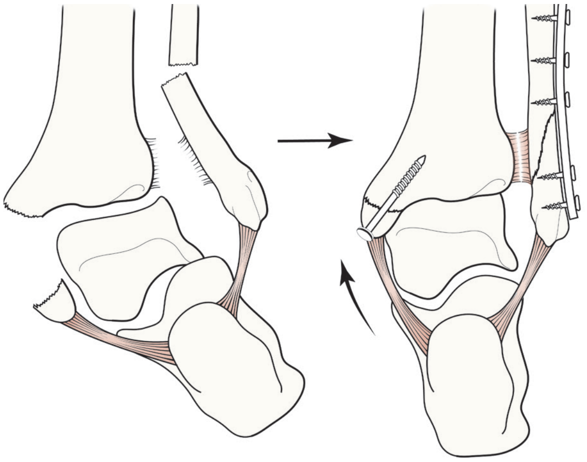

Figure 5.13 *Accurate apposition is necessary when a fracture involves a joint.*

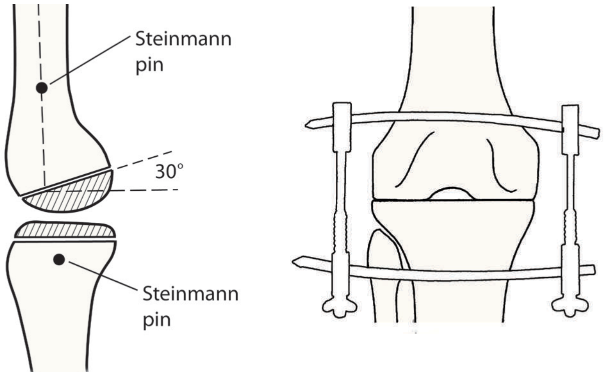

Figure 5.14 *Arthrodesis of a severely damaged knee is an option when a joint replacement is not possible. The articular surfaces are resected and Steinmann pins inserted to which the Charnley compression apparatus is fixed.*

Feet

Most fractures of the feet need no intervention other than support for pain relief. A crush fracture of the calcaneum, however, distorts the subtalar joint, making subsequent degenerative change inevitable. The articular surface can be levered back into position with an instrument inserted into the body of the calcaneum from a posterolateral approach. Severe degeneration can be managed with a triple arthrodesis of the subtalar and midtarsal joints. Much of the elective orthopaedic surgery of the feet follows the general principles of osteotomies to correct malalignment and excision arthroplasties of damaged joints.[1]

AMPUTATIONS: INDICATIONS AND GENERAL CONSIDERATIONS

Amputation of a limb – or part of a limb – is required when the vitality of the part is destroyed by injury or disease or when the life of the patient is threatened by infective, ischaemic (biochemical) or malignant pathology in the extremity. Amputation may also be indicated for a deformed or paralysed limb that is of little functional use to the patient, particularly in instances where a prosthetic limb would be of greater value.

Trauma

In severe trauma the decision of whether to amputate or persevere with limb salvage is not always straightforward. Vessels and nerves can be repaired, and it may even be possible to reattach a totally severed limb if the injury has been a sharp amputation rather than an avulsion. However, in general, if a limb has received a blunt injury that has severed the bone in addition to causing vascular and nerve damage, the final result from salvage surgery is likely to be disappointing. The division of bone is often already completed and can be accepted as the level for amputation if adequate soft tissue cover is possible (Figure 5.15). In other situations, considerations of soft tissue cover dictate the level of bone division (Figure 5.16). In some instances the stump length will have to be shortened to make it suitable for a future prosthesis, but in general extra length is beneficial. If the trauma is recent and relatively clean, it may be possible after careful wound toilet and with antibiotic cover to appose the soft tissue definitively with a few loose sutures over a drain. This may also be appropriate when a patient presents early with an injury such as that sustained from a landmine explosion, provided that wound toilet is meticulous.[6] However, when a patient presents late with such a wound, it is unwise initially to do anything other than excise non-viable tissue and proceed to the fashioning of the definitive stump several days later. Occasionally, amputation is necessary when trauma has caused little damage except that it has severed a major vessel and vascular reconstruction has been impossible or unsuccessful. The considerations are then more ischaemic than traumatic, but with the advantage that the patient does not have the generalised advanced atherosclerosis that complicates most amputations for limb ischaemia.

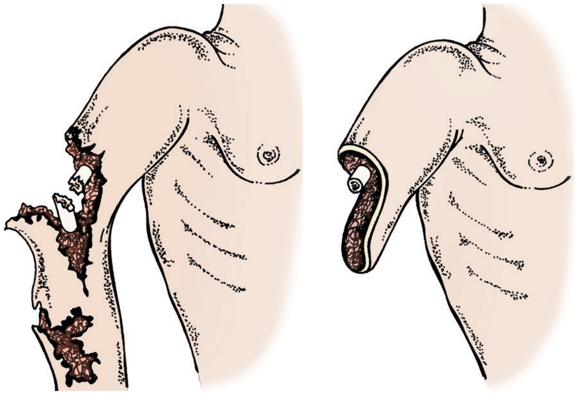

Figure 5.15 *In severe trauma bone division is often complete and dictates the level of amputation if soft tissue cover is possible. A single flap may make the best use of viable soft tissue.*

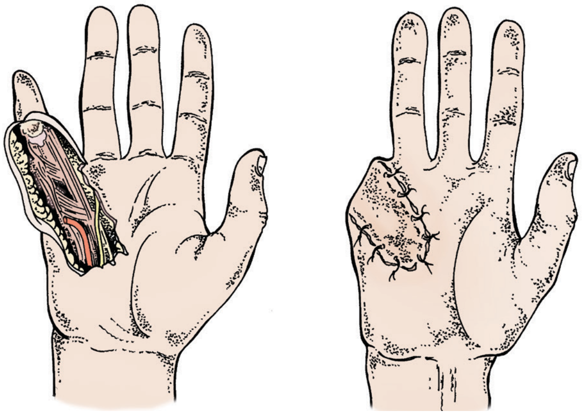

Figure 5.16 *Severe soft tissue loss of palmar skin and tendons necessitates a proximal amputation despite intact bone.*

Deformity and paralysis

In considering the indications for amputation it is necessary to make a clear distinction between the upper and lower extremities. It is important to preserve length and stability in the lower limb. Stability of a paralysed limb, without associated deformity, can usually be achieved with external calliper support. A deformed, shortened, unstable lower limb may be the result of a congenital malformation or be the end result of severe trauma, septic arthritis or osteomyelitis, especially if it occurred in early childhood and the growth of the bone was arrested. Whatever the initial pathology, if corrective surgery cannot achieve a weight-bearing limb, the patient will be better served by an amputation to allow the fitting of a prosthesis.

Stability and length are not crucial to useful function in the upper limb, and a grossly deformed or shortened limb is often of more use than a prosthesis. However, retention of a paralysed upper limb is of little benefit to the patient, who may request an amputation.

Malignancy

In most soft tissue sarcomata, the excision of a compartment of soft tissue is adequate local treatment. In bone sarcomata, advanced reconstructive techniques have allowed radical excision of the bone primary with preservation of the limb. However, a limb amputation is still occasionally the only surgical option. In subungual melanoma, a distal digital amputation is necessary to achieve a radical tissue margin.

Infection

Amputation is indicated as an urgent life-saving intervention in infective gangrene. Gas gangrene is the most serious form of this and is discussed in Chapter 4. Gangrene was traditionally divided into 'wet' and 'dry' gangrene. An infective gangrene is always a wet gangrene. There is a rapid deterioration of the patient due to absorption into the systemic circulation of chemicals released from dead tissue, and delay in amputation inevitably leads to death from multiple organ failure.

Peripheral arterial occlusive disease

Peripheral arterial occlusive disease (PAOD) and diabetes, co-existing to various degrees, account for over 90 per cent of amputations in the Western world. Unless there is already irreversible ischaemic damage, surgical or endovascular restoration of tissue perfusion must be considered initially in an effort to avoid amputation. Amputation is reserved for situations where this has failed or has been shown to be impractical. An amputation may be carried out because of severe intractable ischaemic rest pain and incipient gangrene or for established gangrene. Ischaemic gangrene may be either wet or dry. Urgent amputation is mandatory for wet gangrene. The dry variety, with black desiccated digits or distal foot, is associated with minimal systemic toxicity. There is no urgency for amputation, and eventually demarcation and separation will occur. Awaiting this natural resolution may sometimes result in preservation of more tissue than if an early surgical amputation is performed, but a surgical amputation is usually preferred. This form of dry gangrene is also seen in frostbite. Mixed with simple PAOD are the various degrees of diabetic foot sepsis, some of which respond to local drainage and resection, followed by arterial imaging and reconstruction, while others are best treated by primary amputation.

In general, the amputation is performed at the most distal level consistent with healing, remembering that patients with critical limb ischaemia usually have widespread, multilevel arterial disease. Surgery for gangrene of the toes without successful reperfusion may heal, but usually major amputation at the transtibial (below-knee) or transfemoral (above-knee) level is indicated. It must be remembered when planning an amputation that the tissue perfusion necessary to heal an amputation wound is much greater than that required merely to sustain tissue viability. A relatively small number of mainly diabetic patients have predominately distal small vessel disease and consequently relatively localised peripheral ischaemic changes. In these circumstances it is possible to consider one of the more conservative amputations. Diabetic gangrene is usually of mixed aetiology; a complex interplay of infection, neuropathic trauma and poor tissue perfusion, due to both distal small vessel disease and more proximal occlusive arterial disease. The severity of the latter often makes a local amputation inappropriate.

Many patients are elderly, with poor general mobility and cardiorespiratory reserve. They may manage to walk again after a below-knee amputation, but only rarely after an above-knee amputation. If, however, there is no prospect of successful limb fitting and restoration of full mobility, an above-knee amputation, which results in faster and more secure wound healing, may be appropriate, accepting lesser rehabilitation goals of transfer skills and wheelchair use. It must be remembered that patients with PAOD of their lower limbs are likely to have similar pathology throughout their arterial system. Perioperative mortality and poor late survival after amputation reflect this.

Stump length

Consideration must be given to the function desired of the stump. Even the most fragmentary portion of a hand is of great value to the patient, and should be preserved (Figure 5.17). Overzealous attempts to preserve a foot may be

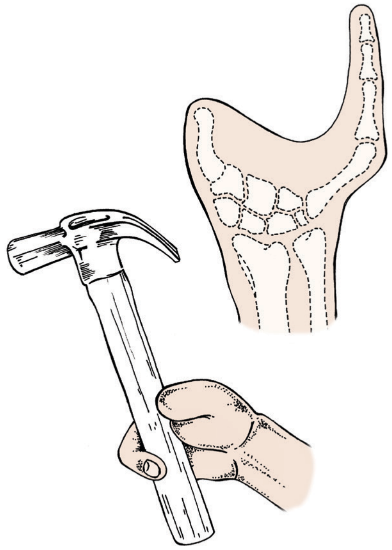

Figure 5.17 *Even a fragmentary portion of a hand is of great value. This drawing is taken from the X-ray and photograph of a man injured in the 1914–18 war. He retained sufficient strength of grip between the 5th finger and the 1st metacarpal to return to manual employment.*

misguided, although the preservation of a weight-bearing heel is of value. Above the wrist or ankle the stump should be fashioned with the aim of fitting a prosthesis. In the upper arm and forearm, a 20-cm stump is recommended. For the lower leg a 14-cm tibial stump is ideal, and a stump of less than 8 cm is difficult to secure in a prosthesis. In an above-knee amputation a 25–30-cm stump measured from the tip of the trochanter is optimum. Amputations through joints are often difficult to fit to a satisfactory prosthesis. These general guidelines should be modified to adapt to local circumstances and the available prostheses (see Figures 5.24 and 5.27).

Stump length in childhood is difficult to judge, as the divided bone loses its distal growing epiphysis and proportional amputation is therefore not appropriate. Bony overgrowth in the immature stump does not significantly increase the length of the stump, but periosteal spikes of new bone cause discomfort and frequently require revisional surgery. In an above-knee amputation in childhood, the major growing epiphysis of the femur is lost and thus very little increase in length occurs. It is therefore essential that as much length as possible is preserved and, if at all possible, a through-knee amputation is to be preferred. Growth in length of the stump is also diminished after a below-knee amputation as the proximal tibial epiphysis fails to contribute its full expected growth. When feasible, a Syme's amputation, which retains the distal growing epiphysis of the tibia, is therefore a good alternative in childhood. Alternatively, a proportionally long 13 cm tibial stump is recommended.

Construction of flaps

A stump to which a prosthesis is to be fitted should be firm and smoothly rounded, and it should be conical in shape, tapering distally. A bony stump has inadequate muscle cover, while a bulbous floppy stump has retention of excessive muscle and skin distal to the division of bone. The skin and soft tissue division must therefore be carefully planned. A *racquet incision*, in which a straight incision is carried proximally from a circular or elliptical incision, is used for disarticulation at the metacarpo- or metatarsophalangeal joint (see Figure 5.19), and is applicable for amputation at the shoulder or hip (see Figures 5.21 and 5.30). Amputation using *flaps* is the most widely used method of amputation. Either two flaps cut from opposite sides of a limb, or a single longer flap, may be used. In order that the bone may be adequately covered, it is essential that the combined length of the two flaps or the total length of a single flap should be equal to 1.5 times the diameter of the limb at the level that the bone is divided. Each flap should be cut to a semicircular rather than a rectangular shape, since a conical, and not a cylindrical, stump is desired. Unequal flaps may be indicated because of tissue loss or to maximise the use of tissue with good perfusion. This also avoids a terminal scar. When unequal flaps are used, the shorter flap should be rather broader than the longer flap so that the skin edges to be sutured are of equal length. A good blood supply to the skin of the flap must be assured, and is a particularly important consideration in amputation for PAOD. As the blood supply to the skin is often partly from the underlying muscle, by vessels that pierce the deep fascia, there are obvious advantages in a combined myocutaneous flap. The muscle, however, may need to be thinned distally to avoid a bulky stump (see Figure 5.26).

NERVES

Nerves are divided cleanly with a knife and allowed to retract into the soft tissues, thus avoiding a troublesome neuroma. Ligation of a major nerve with a fine ligature prevents bleeding from accompanying vessels, but the ligature may be implicated in neuroma formation. Ligation of the sciatic nerve may be necessary if the small accompanying artery has become enlarged as a significant collateral vessel. Phantom pain after amputation may be reduced by perioperative epidural anaesthesia. Immediate postoperative pain can be reduced by injecting the large nerves with long-lasting local anaesthetic if the patient is not given a regional anaesthetic.

BLOOD VESSELS

Blood vessels require ligation. Large superficial veins will be encountered in the subcutaneous fat, and these can be simply ligated. The major vessels of a limb require careful ligation, with ligatures of a gauge and strength appropriate to their size. Double ligation, or a transfixion technique as described in Chapter 1, is recommended. A tourniquet should not be used in amputations for PAOD as any reduction in the perfusion of the flaps may be critical for healing.

BONE

Bone is divided by any of the methods discussed earlier in this chapter, and rough edges removed with a rasp or file. Care must be taken to avoid soft tissue damage while dividing the bone.

CLOSURE

Opposing muscle groups are sutured together over the bone ends, both to cover the divided bone and to balance the muscle action on the stump. Younger patients may benefit from a more formal *myodesis* in which the muscle is secured to the bone ends by sutures passed through drill holes in the bone. Tension-free skin closure is important and, in a major amputation, vacuum drainage is recommended. Postoperatively, the first priority is healing, but care must be taken to maintain the mobility of proximal joints. A stiff hand or a flexion deformity at the hip is easier prevented than treated. In major lower limb amputations there are some advantages in early bandaging of stumps to improve the shape for a prosthesis, and in the application of a plaster to allow early weight bearing through a prosthetic extension. However, these manoeuvres carry some risk of compromising healing in vulnerable stumps with marginally adequate perfusion.

UPPER LIMB AMPUTATIONS

Hand

Amputation of fingers is most commonly undertaken for severe trauma in which there is skin loss combined with additional bone, vessel or tendon damage. The advantages of alternative lengthy reconstruction procedures must be considered, and the correct decision may depend on the patient's occupation and preference, as much as on the extent of the injury. The type of amputation is often determined by the availability of skin and soft tissue rather than by following formal procedures (see Figure 5.16). It is, however, always preferable to cover the bony stump with volar skin and soft tissue. Every effort must be made to preserve as much of the thumb as circumstances will allow, as it is of pre-eminent importance in the hand. Even a stump composed of the metacarpal alone or part of the metacarpal, is of great value (see Figure 5.17). A stiff or deformed finger from previous infection or trauma may hinder the use of the hand and the patient may request amputation. Occasionally, a finger must be amputated for adequate local treatment of a malignancy.

In general, amputation through the base of a phalanx is preferable to disarticulation at the joint immediately proximal, as this preserves the attachments of tendons and intrinsic muscles and results in a stronger grip. An amputation through the base of the proximal phalanx or through the metacarpophalangeal joint of the index or little finger leaves a somewhat conspicuous deformity. The hand has a better cosmetic appearance if the metacarpal head is sectioned obliquely, preserving the attachment of the metacarpal ligament and the metacarpal arch (Figure 5.18). After oblique removal of the metacarpal head, the stump of the metacarpus should be covered by interosseous muscle. Distal amputations of the fingers are best covered by a single volar flap, whereas an equal lateral flap technique is suitable for more proximal amputations. A racquet extension to the incision allows transection of the metacarpal head (Figure 5.19). Difficulty is encountered in digital amputations if the flaps are too short. This will occur if the surgeon is not aware of the surface marking of the joints when planning the flaps. The joints are more distal than is immediately apparent (Figure 5.20).

Arm and forearm

Arm and forearm amputations are not commonly indicated except for major trauma, and they follow the general rules of amputation discussed previously. Bilateral amputations often deprive a patient of independence, although sophisticated

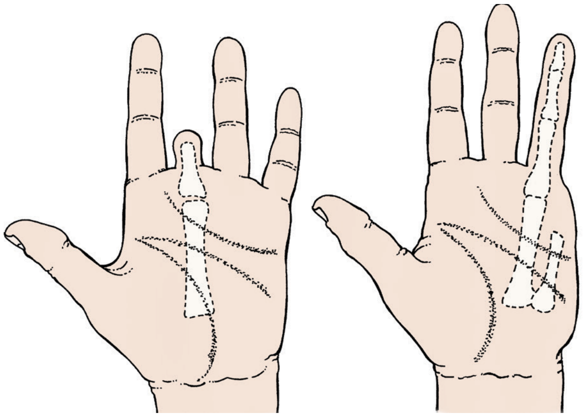

Figure 5.18 *Amputation through the base of a proximal phalanx gives a strong grip. An oblique metacarpal amputation results in a more satisfactory appearance if the index or little finger has to be sacrificed.*

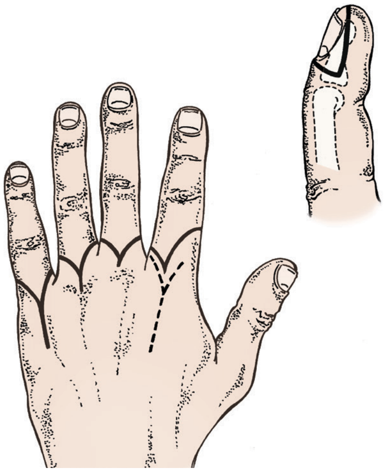

Figure 5.19 *A single volar flap is preferable for a distal digital amputation. Equal lateral flaps are suitable for more proximal amputations. A racquet extension affords access to the metacarpal head.*

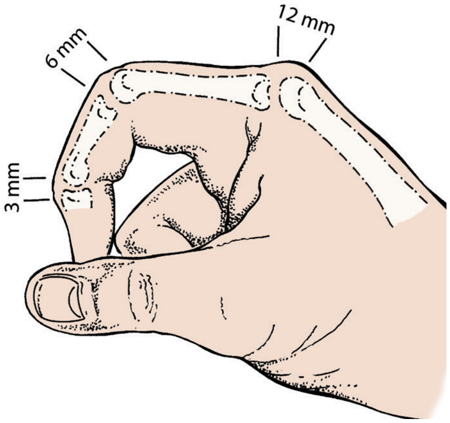

Figure 5.20 *A surgeon unfamiliar with the surface markings of the joints will have difficulty in planning satisfactory flaps. The measurements given indicate the distance of each joint distal to the angle of the knuckle.*

functional prostheses have greatly improved in recent years. Occasionally, after a clean traumatic amputation, a limb has been successfully reattached with microsurgical techniques. Unfortunately, many of these injuries occur during periods of war and its aftermath in areas of the world with limited resources. The *Krukenberg amputation* may have a place when a bilateral forearm amputation is inevitable in these circumstances. The operation separates radius and ulna, thus providing a crude pincer grasp.[7]

Shoulder

Major amputations at shoulder level are seldom indicated. Amputation through the humeral neck preserves the normal contours of the shoulder and is preferable to the more proximal amputations unless they are specifically indicated. For *disarticulation through the shoulder joint* a racquet incision is used (Figure 5.21a). The incision commences at the tip of the coracoid and extends distally in line with the humerus to the axillary folds, where it splits to encircle the arm. The vertical part of the incision is deepened to bone by division of the clavicular fibres of the deltoid and pectoralis. The posterolateral part of the circular incision is then deepened to bone by division of the deltoid muscle close to its insertion. The deltoid muscle is retained in the large lateral flap. The joint capsule and capsular muscles are then divided to allow dislocation of the humeral head. The brachial vessels are secured and the nerves and remaining muscle divided. A *forequarter amputation* is an even more radical procedure, and the loss of the normal shoulder contour is a significant deformity. The linear portion of the racquet incision is along the clavicle, the lateral two-thirds of which is excised (Figure 5.21b). The clavicular excision affords access to the subclavian vessels and the brachial plexus, both of which require division. The pectoral muscles are divided. Posteriorly, the scapula is excised after division of all muscles attaching the scapula to the trunk.

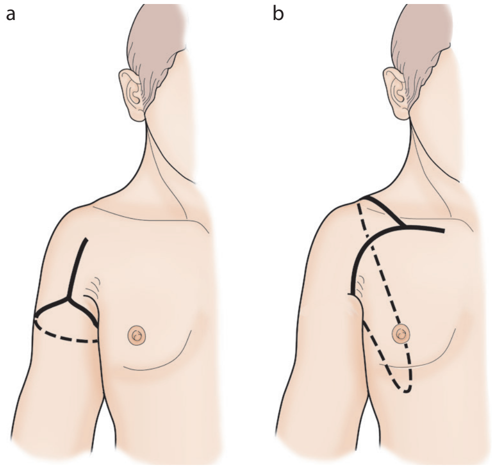

Figure 5.21 *(a) The incision for disarticulation through the shoulder joint. (b) The incision for a forequarter amputation.*

LOWER LIMB AMPUTATIONS

Foot and ankle

Foot and ankle amputations may be for infective gangrene, trauma or frostbite. Ischaemic gangrene of the toes or forefoot from PAOD nearly always indicates that tissue perfusion will be inadequate to sustain the increased requirements of a healing amputation wound at any site below mid calf. A more proximal amputation is thus indicated unless tissue perfusion can be improved by arterial reconstruction or angioplasty.

A *distal amputation* is sometimes appropriate in diabetes. A patient with diabetic neuropathy may be unaware of minor trauma and subsequent infection, and present with localised infective gangrene. Even if there is an ischaemic element to the gangrene, it may only be due to diabetic microangiopathy, and a distal amputation wound may still heal. However, many diabetic patients also have major vessel disease and this should be carefully assessed before recommending a limited amputation. Furthermore, the spread of web space infection can be particularly rapid in diabetic patients.

RAY AMPUTATION

The most common amputation in the foot is a ray amputation of the affected toe together with the distal half of the associated metatarsal (Figure 5.22). This allows good drainage of infected deep spaces of the foot, and the wound is left open. The advisability of a first or fifth ray local amputation should be carefully considered, as healing is more likely to be troublesome.

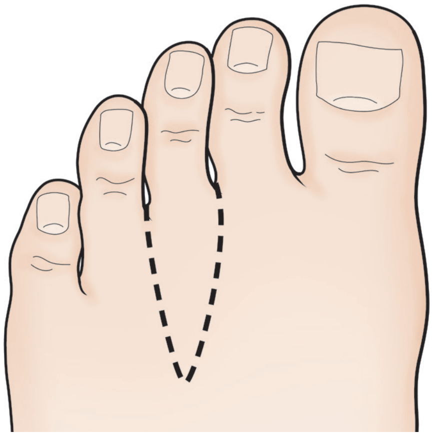

Figure 5.22 *A ray amputation of a toe together with the distal half of the metatarsal will often suffice if distal gangrene is of infective origin.*

TRANSMETATARSAL, TARSOMETATARSAL AND MID-TARSAL AMPUTATIONS

These are also satisfactory amputations for distal gangrene with adequate perfusion of the hindfoot, and leave a patient with a weight-bearing heel. The amputation is undertaken using a long plantar flap, which covers the end of the stump, and the dorsal incision is at the level of bone division (Figure 5.23).

SYME'S AMPUTATION

This classical ankle amputation, first described by Syme in 1842, produces a durable weight-bearing stump, which is often superior in the long term to the forefoot amputations described above. It is particularly suitable in young patients who have sustained a crushing injury to the foot, and is of special value to patients who do not have access to modern artificial limbs. The end of the stump is at a height of about 6–8 cm from the ground and may be walked on without a prosthesis. Alternatively, a simple appliance that raises the stump is inexpensive to manufacture (Figure 5.24). Syme's amputation fell into disfavour in the developed world as there were difficulties in fitting a cosmetically acceptable prosthesis. There has, however, been renewed interest in this amputation.[8] Syme's amputation may have a place in diabetics, but if there is significant large vessel atheroma, it is not suitable.

The incision starts below the tip of the lateral malleolus and is drawn across the sole to a point 2 cm below the medial malleolus (Figure 5.25). The two ends of the incision are then joined by the shortest route across the front of the ankle joint. Throughout the incision, all structures are divided down to bone. Extensor, flexor and peroneal tendons are divided, as are the anterior tibial and plantar vessels and nerves. Vessels are ligated and nerves cut short as discussed previously. The ankle joint is then entered anteriorly and the lateral ligament divided. The foot is then dislocated in a plantar direction to expose the back of the joint.

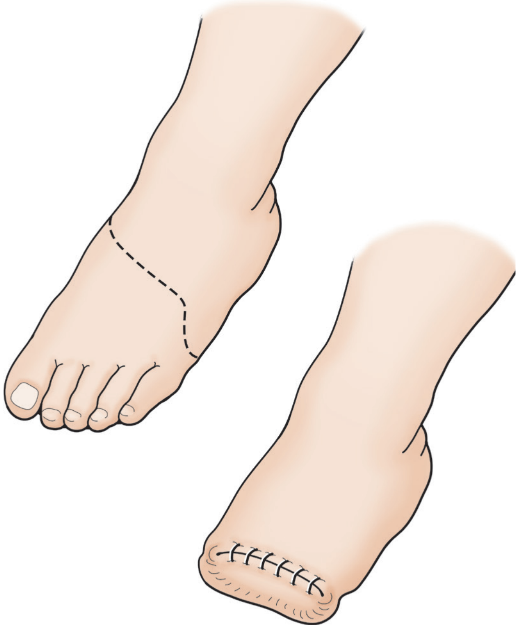

Figure 5.23 *A transmetatarsal amputation for distal gangrene is only satisfactory if the hindfoot perfusion is good. A single plantar flap has the optimum blood supply and also covers the stump with the skin, which is most suitable to withstand trauma.*

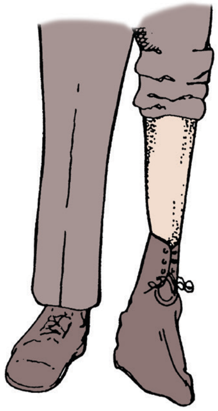

Figure 5.24 *A primitive 'elephant boot' prosthesis that can be used after a Syme's amputation.*

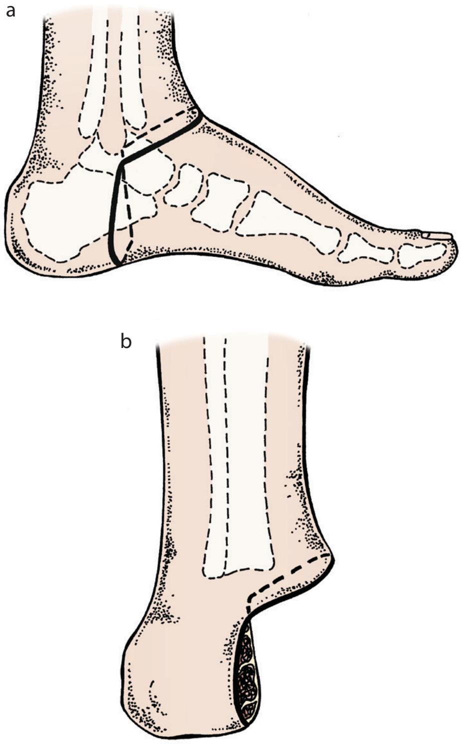

Figure 5.25 *Syme's amputation. (a) The incision. (b) The calcaneum has been dissected out of the heel flap. The malleoli and the distal articular surface of the tibia have been excised.*

The next part of the operation is the most important and the most difficult. It consists of division of the posterior ligaments of the joint, detachment of the insertion of the Achilles tendon and dissection of the calcaneum out of the heel flap. There is great danger of injuring the posterior tibial and peroneal arteries, as both arteries are closely applied to the back of the posterior ligament. Their branches, which supply the skin of the heel, are also in danger when the calcaneum is dissected out of the flap. The knife is kept closely applied to the bone to prevent damage at this stage. The malleoli and a thin slice of tibia are then removed. The saw is applied exactly at right angles to the long axis of the tibia. The heel flap is folded over the bone ends and sutured in position over a vacuum drain.

Modifications

Modifications have been sought to increase the length of the stump. The distal articular surface of the tibia may be left *in situ* and a larger heel flap fashioned by siting the incision more distally, starting 1 cm in front of the medial malleolus. In *Pirogoff's* modification, the posterior part of the calcaneum is retained in the heel flap and is apposed to the sawn surface of the tibia. It is fixed in place by periosteal sutures or fixed internally with a pin. However, the advantages of a full-length, weight-bearing stump are offset by the delay in mobility while awaiting bony union, and this can be a major consideration in the elderly.

Below-knee (transtibial) amputations

These operations are most commonly performed for PAOD and the standard techniques are designed to maximise the use of well-perfused tissue. It is not always possible to retain the ideal 15 cm of tibia, but if less than 8 cm can be retained, there will be difficulty in fitting a satisfactory prosthesis. The long posterior flap is marked out and should be of a length 1.5 times the diameter of the leg. The anterior flap, which has the poorer blood supply, is cut down to bone at the level of bone division. Elevation of the anterior flap of skin and muscle off the underlying bone is kept to a minimum, and 1 cm is adequate. The tibia is then divided and bevelled anteriorly. The fibula is divided 1 cm more proximally.

The posterior flap should retain deep fascia and some underlying muscle throughout its length in order to safeguard skin perfusion. However, the muscle bulk must be reduced to obtain a tapered stump. The posterior muscles are divided obliquely so that virtually all of the deep muscle is removed, and distally, only a thin remnant of the superficial gastrocnemius remains (Figure 5.26). Arteries are ligated as they are encountered and nerves divided so that they can retract. The muscles of the flaps are apposed over the bone with sutures through deep fascia, and the skin is closed over suction drainage. When sawing through the tibia, care must be taken not to deglove the skin over the proximal tibia as the surgeon or assistant steadies the limb. Failure of healing is most common at the most anterior part of the suture line.

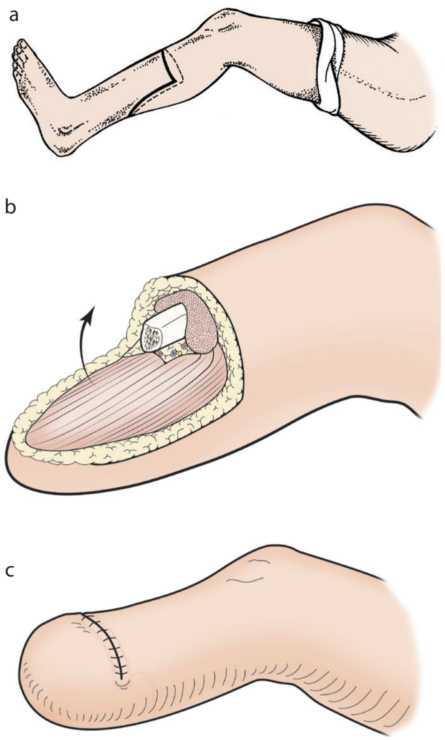

Figure 5.26 *Below-knee amputation. (a) The single long posterior flap utilises the superior blood supply to the calf skin, which is critical for successful healing in peripheral vascular disease. (b) The posterior muscle groups are divided obliquely from the tibia to the skin to reduce the bulk of the flap. (c) The scar is away from the weight-bearing end.*

VARIATIONS

Variations of the standard method are numerous:

- A 'skew' flap technique is favoured by some surgeons.[9] Skin and muscle flaps are fashioned separately. Equal skin flaps are based on the blood supply of the skin, which in this site is anatomically related to the venous drainage of the long and short saphenous veins, and relies on collateral vessels running with the sural and saphenous nerves. A single posterior muscle flap is still used.
- If the patient does not have PAOD, two rather than one musculocutaneous flaps may be preferred. Unequal length of these flaps has the advantage that the scar is away from the end of the stump. Periosteum may be raised from the tibia distal to the level of bone resection, preserved and swung over to the fibula to form a periosteal bridge between the bones. This may form a better stump for a young active amputee.
- A very short stump, although generally unsatisfactory, may be ideal for a primitive prosthesis (Figure 5.27).

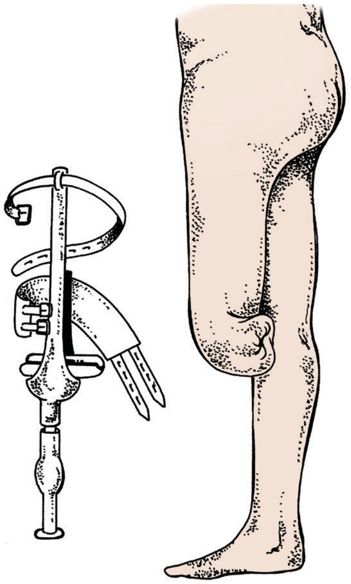

Figure 5.27 *A young man from a remote village presents 5 years after trauma requesting an amputation of a useless flail extremity. There is a flexion deformity of the knee, an ununited fracture of the tibia and a deformed foot in fixed equinus. He is already ambulant with a home-made prosthesis in which he kneels. The limb fitting services are rudimentary. A high below-knee amputation, although unconventional, may be the best solution. Individual patient requirements and local prosthetic facilities should influence the choice of amputation.*

Disarticulation through the knee

This amputation produces a stump that is functionally satisfactory and that can sustain end weight bearing. As discussed previously, a through-knee amputation has advantages in children in order to preserve final femoral length. However, the bulbous end and the external hinge usually required in the prosthesis can make a through-knee amputation cosmetically inferior to other alternatives. In PAOD, if the tissue perfusion will not sustain the healing of a below-knee amputation, a through-knee amputation will probably also be problematic, and an above-knee amputation becomes a better option.

The operation may be performed with equal medial and lateral skin flaps or with unequal anterior and posterior flaps. The patient is placed prone and the flaps raised. Access to the joint is from the popliteal fossa, where the artery is ligated and nerves divided. The posterior muscles and joint capsule are divided and the knee flexed before division of the patellar tendon at its attachment to the tibia. After division of the cruciate, medial and lateral ligaments, the amputation is complete. The patella is retained. The patellar tendon is sutured to the cruciate ligaments and the remains of the extensor retinaculum to the hamstrings.

VARIATIONS

Variations of the standard through-knee amputation include the classical *Gritti–Stokes* amputation (Figure 5.28) and various subsequent modifications of it. The Gritti–Stokes operation is normally performed with the patient supine. Unequal anterior and posterior flaps are raised. The long anterior flap extends down to the patellar tendon insertion, which is divided and the knee joint entered. All soft tissue posteriorly is divided and the femur is then divided immediately above the femoral condyles. The patella, from which the articular surface has been removed, is swung over so that it lies over the divided femur. Stabilisation can be achieved with wire sutures, passed through drill holes in the bone of the patella and femur, and the patellar tendon is sutured to the hamstrings. This amputation lost popularity because of difficulties with prostheses but, with this overcome, there has been some renewed enthusiasm.[10] The removal of the femoral condyles makes it more suitable than a through-knee

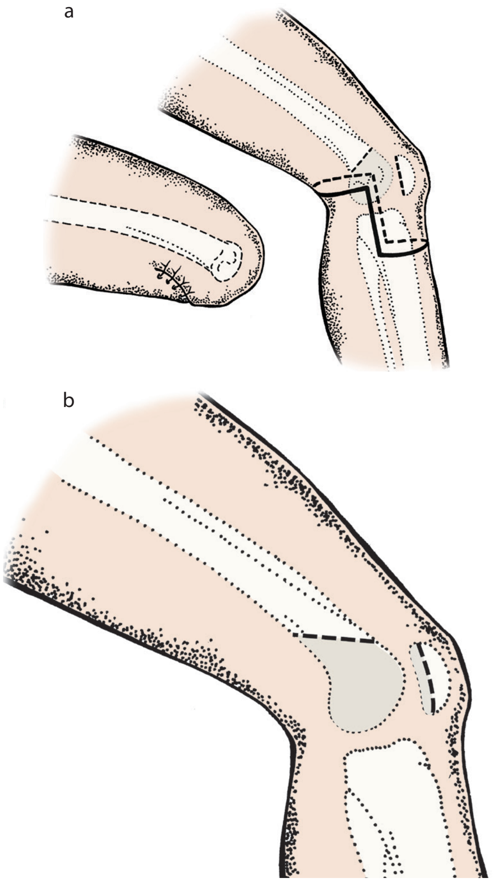

Figure 5.28 *(a) Gritti–Stokes amputation. A long anterior flap brings the scar posteriorly. The femur is transected immediately above the condyles. The patella is retained, but its articular surface is removed before it is fixed to the divided femur. (b) A modification in which the femur is transected at an angle to give superior early stability.*

amputation if the tissue perfusion is marginal. An oblique division of the femur with a 30 degrees angle has been a useful recent variant, giving better early stability (Figure 5.28b).

Above-knee (transfemoral) amputations

These are common amputations for ischaemia and for trauma, and the priorities for the surgeon in different circumstances vary. In general, the longer the stump the better the control of the prosthesis, and ideally 70 per cent of the femur (or around 25–30 cm as measured from the tip of the greater trochanter) should be retained. If the stump is longer than this, the same problems arise with a knee joint prosthesis as with the through-knee and Gritti–Stokes amputations. In a child every effort should be made to preserve the whole femur, as already discussed. The underlying pathology sometimes dictates an amputation in the upper third of the femur, but if less than 10 cm of femur can be preserved, then disarticulation through the hip joint may be preferred in a younger patient in order to fit a more satisfactory prosthesis. In contrast, a short femoral stump, even one with a flexion deformity, is better for the wheelchair-bound amputee.

The operation can be performed with either equal anterior and posterior myocutaneous flaps or unequal flaps with a longer anterior flap (Figure 5.29). The quadriceps muscle is sutured to the hamstrings so that muscle action on the stump remains balanced. In a younger patient some form of more formal myodesis should be carried out.

Gas gangrene is a much feared postoperative complication, particularly after an above-knee amputation for ischaemia. Prophylactic antibiotics must be chosen that are effective against *Clostridium perfringens*.

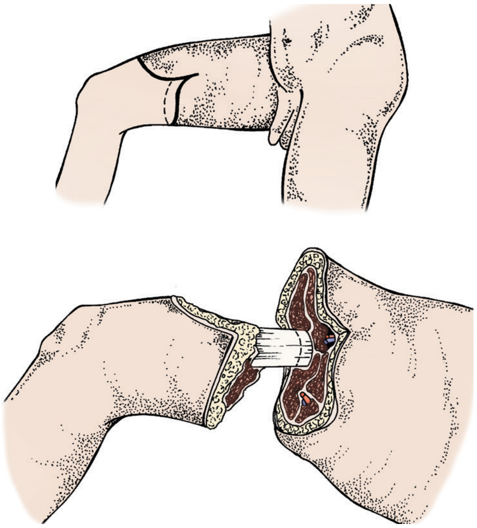

Figure 5.29 *An above-knee amputation. A two-flap technique is suitable for an amputation through the lower, middle or upper femur. A slightly longer anterior flap avoids a terminal scar.*

Disarticulation at the hip joint

This radical amputation may sometimes be indicated if insufficient femur can be preserved to make a satisfactory femoral stump. Two classical approaches to this amputation have been described: (1) the anterior racquet method and (2) the single posterior flap method. The second method may yield a better stump for limb fitting. The incisions for the two approaches are shown in Figure 5.30. In the anterior racquet incision, the 'handle' is placed in the line of the femoral vessels and the medial flap is longer, so that the scar will fall away from the perineum. In the alternative single posterior flap method, the length of the flap should be 1.5 times the anteroposterior diameter of the limb at the level of the hip joint; the anterior part of the incision is 2.5 cm below and parallel to the inguinal ligament. In each method the first part of the operation consists of exposure and ligation of the femoral vessels. The anterior muscles are divided in the line of the incision and the joint is opened from the front. The adductors, the hamstrings and gluteus maximus are cut so that portions of them remain in the flaps. The sciatic nerve is found deep in gluteus maximus and is cut short. Disarticulation is completed by division of the capsule and of the remaining short muscles that are inserted into the trochanteric area. The flaps and muscles are trimmed to give reasonable bulk, without flabbiness, to the stump.

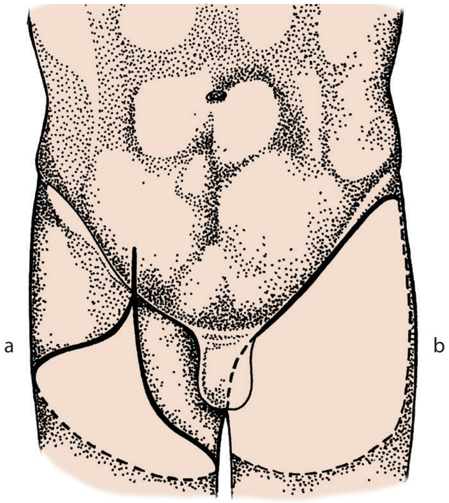

Figure 5.30 *Incisions that may be used for amputation at the hip. (a) A racquet incision with a longer medial flap. (b) A single posterior flap.*

Hindquarter amputation

This mutilating radical amputation is fortunately seldom performed, but is occasionally indicated for locally advanced malignancy[11] or, in exceptional circumstances, when an above-knee amputation has failed in a patient with PAOD. An elliptical incision passes from the iliac crest laterally to the perineal crease medially. The anterior abdominal muscles are divided in line with the incision. The deep epigastric vessels are ligated and the symphysis pubis divided. The peritoneum and ureter are swept medially to expose the common iliac vessels, which are ligated in continuity to reduce blood loss during dissection. Alternatively, this initial ligation can be solely of the internal iliac artery, distal to the origin of the superior gluteal artery, to safeguard the blood supply of the posterior buttock flap. The ilium is divided through the greater sciatic notch and the major portion of gluteus maximus is retained. The remaining soft tissue is divided and all nerves are cut cleanly. The external iliac, obturator, gluteal and pudendal vessels must be ligated before division, even if the common iliac was ligated, as there is usually considerable cross circulation from the other side.

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6

VASCULAR SURGICAL TECHNIQUES: VASCULAR ACCESS AND TRAUMA

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VASCULAR DISSECTION AND CONTROL

The first step in any procedure is exposure and isolation of the vessels. During dissection it is important to stay on the surface of the artery or vein and to mobilise sufficiently to gain proximal and distal control of the area of interest. It is also important to advance on a broad front, avoiding following a vessel into a narrow space with no scope for control of unexpected haemorrhage. All vessels should be handled gently, as trauma to the wall may lead to local thrombosis or wall disruption with bleeding. Clamps should be applied with the minimal compression required to control flow, thus minimising the risk of injury, as a flap or dissection can result from even an apparently minor intimal injury.

VASCULAR ANATOMY

The wall of an *artery* consists of three layers:

- The outer layer, or *adventitia,* is composed of fibrous and elastic tissue and contains the periarterial sympathetic nerves; it is attached only loosely to the middle layer and can be stripped from it without difficulty.
- The middle layer, or *media,* constitutes the main thickness of the arterial wall; it is composed of smooth muscle with a proportion of elastic tissue, this proportion being greater in the large vessels.
- The inner layer, or *intima*, lines the lumen of the vessel; it is a thin layer consisting only of endothelial cells supported on a basement membrane of elastic tissue, which lies in contact with the media.

A *vein* has a similar structure to that of an artery, except that all layers, especially the media, are thinner.

Management of haemorrhage

In all settings, adequate exposure and control of vessels is the first objective of a vascular procedure. In vascular trauma or spontaneous rupture of an abdominal aortic aneurysm the principles are the same – expose and control the appropriate vessel and do not attempt direct dissection of the bleeding site. Major bleeding in limb trauma may be controlled by elevation combined with firm local pressure, or by a pneumatic tourniquet cuff to occlude the vessel proximal to the site of injury. This temporary control allows the patient to be resuscitated and prepared for a definitive operation with adequate lighting and necessary facilities. No attempt should be made in an emergency to clamp blindly at a profusely bleeding vessel as there is a risk of injuring neighbouring structures or enlarging the vascular defect in the vessel, or vessels, that are bleeding. Venous bleeding may be profuse but local pressure and the utilisation of gravity to reduce venous pressure will normally control the immediate problem.

When haemorrhage is from an intrathoracic or intra-abdominal vessel, local external pressure is impractical. Maintenance of circulating volume is essential, but permissive hypotension may be justified. It is important in this situation to consider establishing vascular control as a fundamental part of the resuscitation process. Surgical control is an important option but the interventional radiologists may have a better chance of arresting the haemorrhage quickly and effectively. Initial surgical or radiological control may be more proximal than is ideal. For example, the aorta can be cross-clamped just below the diaphragm for the initial control of life-threatening upper abdominal haemorrhage if speed is vitally important. When control has been achieved, the position of a clamp, local pressure or occluding balloon can then be revised for more appropriate control closer to the site of damage. The focus of management will then shift to the restoration of distal perfusion by repair or reconstruction of vessels.

ESTABLISHING CONTROL

Vascular clamps or tapes

Vascular clamps and tapes placed above and below the site of an arteriotomy or injury are the most versatile method of control (Figure 6.1). Great care must be taken to avoid injury to structures lying in close proximity to the artery; for example, the left renal vein can be injured when the aorta is cross-clamped, or the common iliac veins while attempting to control the common iliac arteries. The principles of proximal and distal control are identical in venous surgery.

Vascular occlusion clamps are designed to hold a vessel occluded with minimal damage to the vessel wall. Unfortunately, if a vessel is diseased, the distortion of its shape by the clamp may fracture an atheromatous plaque and result in the development of an intimal flap. This, in turn, may lead to either a flow-limiting dissection, local thrombosis or distal embolisation. Damage may occur when a clamp twists after application, and securing the handles of clamps to the drapes will help reduce the likelihood of this occurring. Slings of tape, fine silastic tubing (sloops) or heavy silk ties are alternatives to a clamp. A side clamp on a major vessel may be sufficient, with the advantage that distal flow is preserved (Figure 6.2).

Tourniquets

Tourniquets are rarely used in elective vascular surgery as atherosclerotic vessels may be permanently damaged by external occlusion, but this does not preclude tourniquet use in trauma, particularly in younger patients. The reconstruction may take several hours, so the tourniquet should be released as soon as local control is established, offering the distal tissues some perfusion through collateral pathways. Alternatively, a shunt should be considered. There may be a reactive hyperaemia following tourniquet release with resultant local bleeding. This should not present too many difficulties but if it does, the tourniquet can always be reinflated again so that surgery can continue.

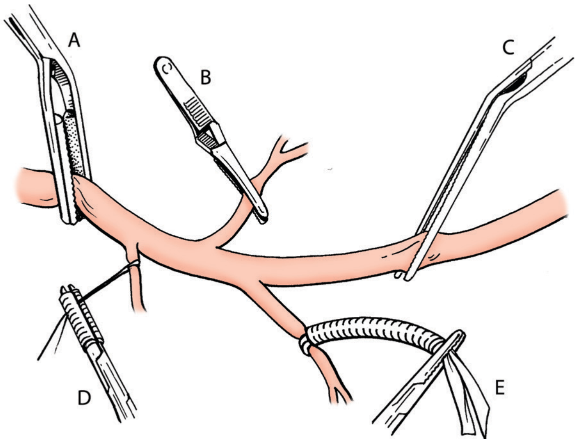

Figure 6.1 *Methods of controlling blood vessels. A = Fogarty soft jaw clamp; B = bulldog clamp; C = atraumatic metal-jawed vascular clamp; D = double ligature sling; E = sling with a vessel occluding snub.*

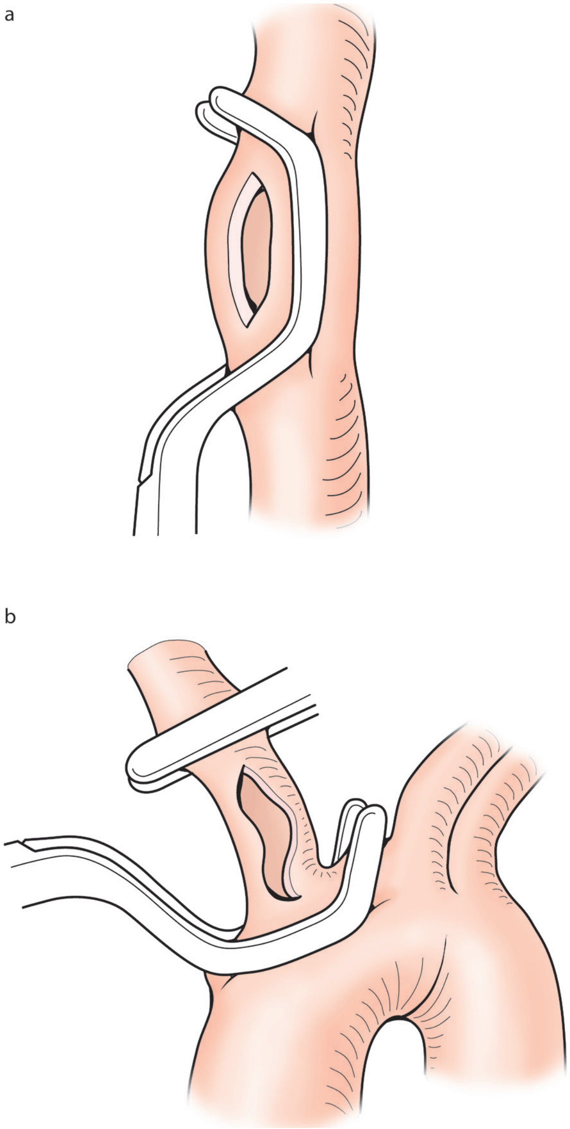

Figure 6.2 *An angled or curved side clamp can isolate part of the circumference of a large vessel while maintaining patency. (a) The control of an iatrogenic laceration in the inferior vena cava with a Satinsky clamp. The laceration can now be repaired without continuing haemorrhage. (b) A curved side clamp is isolating the root of the brachiocephalic artery with its traumatic tear. Flow through the aortic arch is maintained.*

Intraluminal balloons

An intraluminal balloon (such as a Fogarty catheter) is an option to control bleeding if the vessel is inaccessible for application of a clamp or sling above or below the site of surgery (Figure 6.3). Once again, the option of an occlusion balloon positioned under radiological control should be considered.

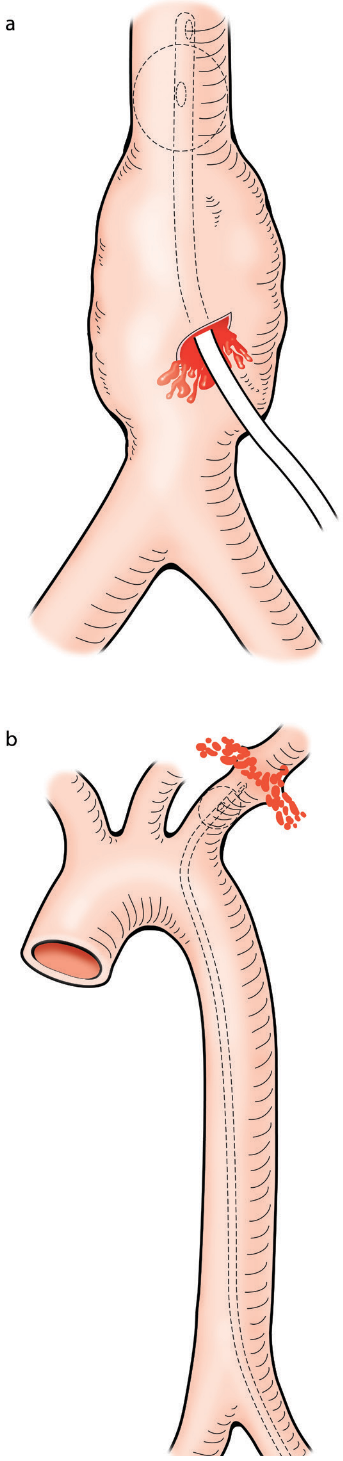

Figure 6.3 *An intraluminal balloon catheter is valuable for proximal arterial control in situations where direct access to the artery is difficult. In (a) the catheter has been introduced through a ruptured aortic aneurysm to occlude the inflow, while in (b) it has been introduced through the femoral artery to occlude the root of the subclavian artery proximal to a traumatic rupture.*

CONSEQUENCES OF VASCULAR OCCLUSION

It is not only the tissue distal to a clamp that is affected by vascular occlusion. A proximal aortic clamp increases peripheral resistance, increases the afterload and may precipitate cardiac instability. The release of such a clamp has even more profound cardiovascular effects. Skilled anaesthetic care is required as many patients are arteriopaths with compromised coronary, renal and cerebral vasculature. Close collaboration between the anaesthetic and surgical teams is essential.

Tissue ischaemia

The sensitivity of different tissues to ischaemia varies. Irreversible ischaemic damage to the cerebral cortex may occur within minutes, whereas a limb remains salvageable for several hours after total vascular occlusion. The kidneys, liver and gut form an intermediate group. It is often difficult to predict whether vascular occlusion is complete or whether perfusion continues at a slightly or significantly reduced level, as there are anatomical variations in arterial arcades. In addition, there may be changes in other arteries secondary to disease. This may take the form of additional stenoses or enlarged compensatory collateral channels. Collateral pathways providing adequate perfusion for a normotensive patient may be inadequate if the patient is shocked. If there is a danger that during the period of arterial occlusion distal perfusion may be inadequate, a temporary shunt should be considered (see below).

Stasis in the vascular tree distal to a clamp is inevitable and thrombosis may follow. *Heparinised saline* (2,000 units of heparin in 500 ml saline) should be instilled into the vessel distal to the clamp, often in addition to systemic heparinisation.

The surgeon must remain aware of the deterioration that occurs in the tissues distal to the vascular control. An excellent technical reconstruction capable of restoring long-term perfusion is wasted if irreversible ischaemic damage to distal tissue has been allowed to occur during the perioperative period. Efficient, effective surgical technique is important to reduce ischaemic time. The circulation can sometimes be partially restored before the end of the entire procedure. For instance, after completion of the proximal anastomosis in a femoral–popliteal bypass, perfusion can be restored to the profunda system before the distal anastomosis is completed.

Ischaemic damage to muscle results in swelling following reperfusion. This swelling, within a closed fascial space, causes a rise in pressure. As interstitial pressure increases, perfusion will decrease as a result of both reduced arterial inflow and impairment of venous return. A vicious cycle with further ischaemic damage occurs and a *compartment syndrome* is established, as discussed in Chapter 4. This is of particular concern when dealing with lower limb vascular trauma, especially a crush injury that may have caused direct muscle injury as well as ischaemic damage. A *fasciotomy*, as described in Chapter 4, should always be considered after a vascular repair in these circumstances.[1]

Renal function may be compromised after major vascular surgery, such as that for a ruptured aortic aneurysm.[2] The mechanism of renal insult leading to acute tubular necrosis is generally multifactorial, resulting from the interplay of hypovolaemia, nephrotoxic agents such as radiological contrast or antibiotics, and cardiovascular changes caused by clamping the aorta (in some instances compounded by renal ischaemia if a suprarenal clamp is necessary) and the subsequent reperfusion.

Any ischaemic tissue below an aortic cross-clamp releases inflammatory cytokines, free radicals, activated white cells and other toxic metabolites into the circulation. These substances invoke a cascade of damage throughout the body, including myocardial depression and acute lung and kidney injury. Skilled intraoperative care, efficient surgery with a short ischaemia time and good postoperative intensive care facilities all improve results.

Temporary shunts

Temporary shunts are indicated when there is concern that irreversible damage may occur to distal tissue during the period of ischaemia (Figure 6.4). Shunts are frequently employed during carotid surgery (see Chapter 7). Even though a normal Circle of Willis will maintain adequate perfusion to the cerebral cortex from a single carotid artery, this cannot be guaranteed in an individual patient. Shunts also have a place in managing the severely injured limb, especially if there is unstable skeletal damage. If possible, fractures should be stabilised prior to vessel reconstruction, otherwise damage to the reconstructed vessel may occur during manipulation of the fracture or joint. However, delay before revascularisation of the distal limb is critical when there have been several hours of ischaemia during transfer to hospital. A temporary shunt followed by skeletal fixation and, finally, a definitive vascular reconstruction may be the best solution.[3] Silastic tubing may be satisfactory for a temporary shunt, but a specifically designed shunt is clearly advantageous. The Pruitt–Inahara shunt has a balloon cuff at each end which, when inflated, fits snugly against the intima: the Javid shunt has a groove around which shunt clamps are placed.

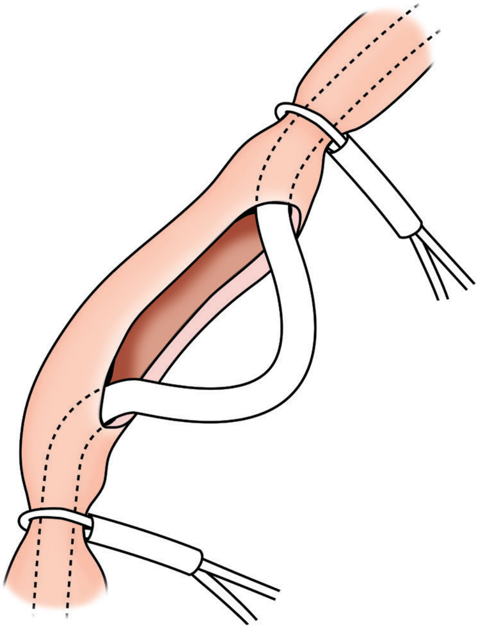

Figure 6.4 *A temporary shunt maintains distal tissue perfusion while still allowing the surgeon good access in a dry field.*

VASCULAR SURGICAL TECHNIQUES

As with all operations, vascular repair or reconstruction is best performed in optimum circumstances with appropriately experienced staff. Sterility, adequate light, suction and instruments are all essential. The basic vascular techniques are similar for arterial and venous surgery, with exposure and control of the relevant vessels preceding any procedure. Vascular anastomoses and vessel repairs are performed using non-absorbable monofilament sutures. These slide atraumatically through the vessel wall and create the least tissue reaction. Soft, pliant, monofilament polypropylene is most favoured. A useful standard size of suture for femoral and popliteal arteries is 5/0. Finer sutures are used for smaller vessels, while 3/0 may be used for the aorta. Round-bodied needles are the most suitable for normal vessels, but a tapercut needle may be better for suturing dense graft material or heavily diseased arterial wall. The sutures commonly have a needle at both ends (*a double-ended suture*). During vessel closure, care must be taken to include all layers of the arterial wall, and especially the intima, in every stitch (unless of course an endarterectomy has been performed). Dissection within an intimal flap is probably the commonest cause of early thrombosis after reconstruction. A needle passed from the outside of the artery to the inside is in more danger of lifting a flap of diseased intima than a needle passed from within out. When a needle has to be passed from without in, the intima should be supported against the vessel wall as the needle is inserted (Figure 6.5). Monofilament sutures are easily damaged and must not be handled with metal instruments as they may fracture. The damage is not always obvious and the suture, although apparently intact, is prone to breaking later with minimal strain. If one end is to be held temporarily, a rubber-shod clamp should be employed.

Arterial ligation

A ligature of appropriate diameter and strength for the size of the artery must be selected. A transfixion ligature gives extra security, especially if the stump of an artery beyond the ligature is short. Oversewing a vessel will give an even more secure closure than a transfixion ligature, and is used when a very major vessel must be closed. Arterial stapling devices are another secure alternative.

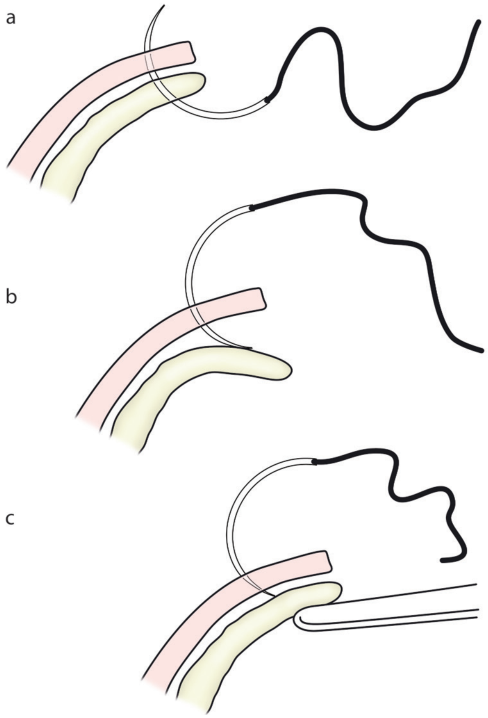

Figure 6.5 *(a) A needle passed from within out presses an intimal atheromatous plaque safely against the vessel wall. (b) When passed from without in, it may separate off the plaque and initiate a dissection. (c) This separation is prevented by supporting the intima with an instrument.*

Arteriotomy

The site and orientation of an arteriotomy are determined by the purpose for which it is intended and also by the distribution of local disease. Local disease can be removed to allow anastomosis or vessel closure, but this can still leave the surgeon in a situation where stitching is difficult and occasionally impossible. Careful planning is therefore essential. An arteriotomy may be performed to deliver an intraluminal device, to remove a thrombus or embolus, to excise atheroma or to create an inflow or outflow anastomosis for a graft. Most commonly, a longitudinal arteriotomy is preferred. The access to the lumen is good and can be improved by extending the arteriotomy proximally or distally. Primary closure will, however, narrow the vessel. This may not matter much in a large-calibre vessel but it may defeat the purpose of the procedure entirely in smaller vessels. Closure around a patch maintains the lumen. A transverse arteriotomy is suitable for removing a thrombus or embolus from healthy vessels and is also suitable for opening grafts. Occasionally, a transverse incision is best for femoral vessels if there is posterior plaque and the jaws of the clamp are also orientated in the medial-lateral plane.

An arteriotomy can be closed with either continuous or interrupted sutures. As the end of the closure is approached, it may become more difficult to ensure that all layers are included in the stitch. It is therefore advisable that a separate end stitch should be placed at the opposite end of the incision, as shown in Figure 6.6. The stiches should draw the cut edges together with slight eversion, thus encouraging intimal apposition with exclusion of the non-intimal layers from the lumen. A large vein can be sutured in a similar fashion to an artery, but the wall is more delicate and more elastic.

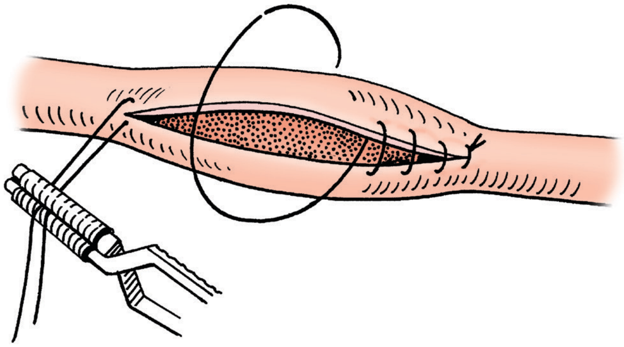

Figure 6.6 *Closure of an arteriotomy.*

Balloon embolectomy

The balloon embolectomy catheter, famously designed by Fogarty when he was a medical student,[4] is available in sizes 3 to 7F. It is usually 60–80 cm long and has an inflatable balloon close to its tip. The catheter is inserted through an arteriotomy and advanced to a point beyond the presumed extent of the embolic or thrombotic material. The balloon is inflated until slight resistance is felt and the catheter is then withdrawn, the balloon bringing with it any emboli and thrombus within the lumen. Inflation should be gradually increased to match the widening calibre of the artery if the catheter is being withdrawn from the distal arterial tree. If it is being withdrawn from larger proximal arteries, the balloon must be gradually reduced in size. Gentleness is essential to minimise intimal damage. Atheromatous plaques can be felt as areas of roughness as the balloon is drawn up or down the artery. The artery may narrow significantly at these points and if the operator does not actively let fluid in or out at each point, significant damage can result, including stripping of the endothelium. A similar technique can be employed for thrombotic occlusion of a bypass graft. In a synthetic graft, which lacks an intimal lining, successful clearance can be achieved even after several days have elapsed.

Venous thrombectomy and embolectomy have been virtually replaced by intravascular thrombolytic techniques.

Endarterectomy

The atherosclerotic pathology that occludes arteries is mainly within the intima, with a variable extension into the media. A surgical plane of cleavage can usually be indentified between an atheromatous plaque and the outer layers of the vessel wall. A variable thickness of media will be excised with the atheroma. Endarterectomy is undertaken through a longitudinal arteriotomy. It is important to leave a smooth interior to the cleared artery. This can be difficult where endarterectomy meets the more normal intima at the distal limit of the excision. Any intimal step at the distal extent of the endarterectomy must be avoided or corrected as blood flow may lift this edge off the vessel wall, with subsequent flap, thrombosis or dissection. If a gently shelving intimal plaque edge cannot be achieved, then fine tacking sutures may be required to hold this thickened intima against the vessel wall. The arteriotomy is then closed, most frequently with a patch.

Patch closure

Simple sutured closure of a longitudinal incision in any artery may result in vessel stenosis. Closure with a patch should be considered if the calibre of the vessel is such that primary repair may result in significant narrowing (Figure 6.7). Autogenous saphenous vein is generally the most suitable material for a vein patch. Ideally, the proximal part of the long saphenous vein (LSV) should not be sacrificed for this as it may be required for future reconstructive surgery. A suitable patch can be harvested from the ankle or from one of the larger tributaries to the saphenofemoral junction. This autologous material can be shaped into a patch or cuff. The ends of the elliptical patch are where technical difficulties arise. It is therefore recommended to parachute the distal 'toe' end with a double ended suture, either at one side of, or directly at, the toe to allow access to view the placement of each stitch in this crucial area. A patch of *expanded polytetrafluoroethylene* (e-PTFE) or Dacron™ (polyester) can be used if suitable vein is not available. *Bovine pericardial* patches have been adopted in clinical practice. These patches handle well and may be more resistant to infection than other non-autologous alternatives.

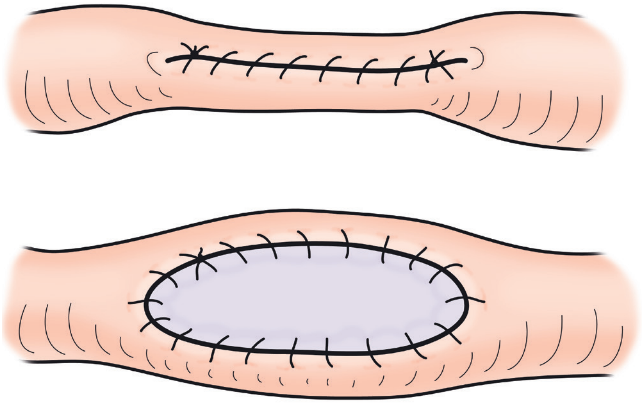

Figure 6.7 *Simple closure of an arteriotomy may result in a stenosed segment. This can be avoided by using a vein patch.*

Vascular anastomoses

There are many different techniques for joining blood vessels to each other and to grafts. In constructing an end-to-end anastomosis, care must be taken to avoid narrowing the lumen, and it is preferable, except in the largest vessels, to bevel the ends (see Figure 6.9). It is usually more convenient to use continuous sutures, but interrupted sutures should be used in children where subsequent growth is anticipated. Interrupted sutures are also preferable in very small or delicate vessels. Children's vessels must be handled with great care, as they are particularly prone to spasm.

Broadly, there are two techniques for performing an end-to-end or an end-to-side anastomosis. The first is to place anchoring sutures and rotate the vessel so that all sutures are placed from outside. The second technique, of parachuting the anastomosis together, is necessary when there is insufficient vessel mobility. Again, the anastomosis should lie with slight eversion of the cut edges.

END-TO-END ANASTOMOSIS

End-to-end anastomoses can be difficult if one or both ends are free. Stay sutures, placed as three interrupted anchors equidistantly around the circumference, will help (Figure 6.8).

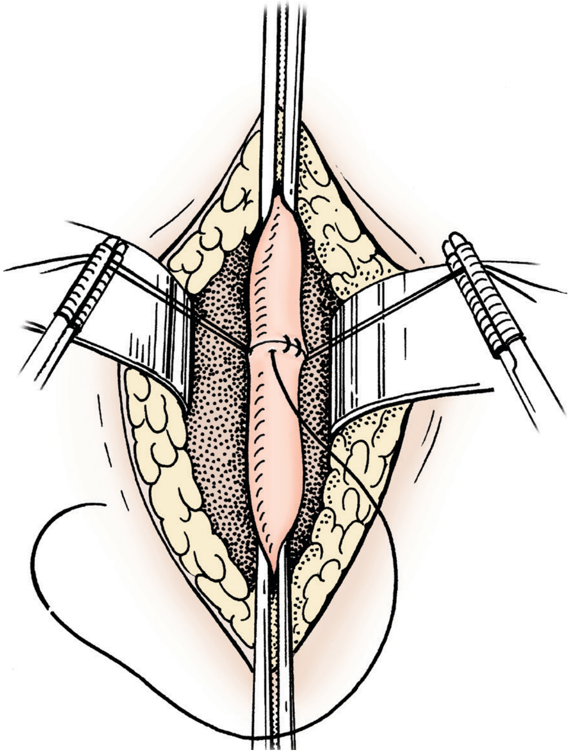

Figure 6.8 *Interrupted anchoring sutures are placed first to unite the vessel equidistantly around the circumference. The ends of these sutures are left long and held in forceps. The anastomosis is then performed with a continuous suture between these anchoring sutures, which are used to rotate the vessel for access. The continuous suture should slightly evert the edges.*

More commonly, a posterior row of continuous sutures is initially placed intraluminally, with the cut ends of the vessel still some distance apart (Figure 6.9). The frictionless quality of polypropylene allows the ends to be parachuted together. The front of the anastomosis is then continued from without, using both ends of the double-ended suture. Vessels (and grafts) are 'flushed' prior to completing an anastomosis. Flushing is performed firstly by releasing the proximal and distal clamps in turn to expel the blood, and possible clots, from the vessels immediately above and below the anastomosis. Heparinised saline is then injected intraluminally both upstream and downstream to rinse the vessel free of any thrombus or plaque debris that could cause distal emboli. The anastomosis is then completed and the two ends of the suture tied together before the clamps are finally released. Minor leakage from an anastomosis will cease with local pressure. Areas of significant bleeding will require a further suture. Clamps should be reapplied before doing this as the vessel may tear and the situation worsen if a suture is inserted with a poor view of the anastomosis. Whether figure-of-eight or mattress sutures are used, they can be buttressed with Dacron™ or PTFE pledgelets or, alternatively, with an autologous pledget of abdominal wall fascia, vein or even a small piece of fat.

END-TO-SIDE ANASTOMOSIS

An end-to-side anastomosis follows similar principles. It is commonly performed between a diseased vessel and a bypass graft. An arteriotomy in the vessel, the length of which is two or three times the diameter of the graft, forms the 'side' for the anastomosis. The 'end' of the artery, vein or synthetic graft is bevelled, as this allows it to lie naturally without kinking, reduces the angulation that causes blood flow turbulence and produces a wider end for the anastomosis. An incorrect angle will predispose to folding or kinking. This may happen in some places if the final position of the vessels on closure of the wound is not taken into consideration. If access is unrestricted, a double-ended suture is placed first at the 'heel' and a second similar suture at the 'toe' (Figure 6.10). All sutures can then be placed from without. If access is more restricted, a double-ended suture is placed at the heel and then the back row of continuous sutures placed from within before the ends are parachuted into apposition. The anterior portion of the anastomosis is then completed from without (Figure 6.11). Continuous or interrupted sutures, or a combination, are suitable. A continuous suture is more haemostatic and quicker, but may narrow the heel or toe of a graft anastomosis. Interrupted sutures, particularly if left untied until all have been placed, allow a clear view for the insertion of each stitch, but the process is time-consuming and the artery may distort unexpectedly as the edges are drawn together. For some anastomoses, for instance radiocephalic fistulae and bypasses to the crural vessels, a hybrid technique can be employed; a continuous line of suture for the most part, with interrupted stitches at the heel and especially the toe of the anastomosis. A few moments consideration regarding the set-up of the anastomosis is always worthwhile. The access and view should be good for the key areas of the heel and the toe, the direction of travel should minimise crossing of sutures and the anastomosis should be finished on the side closest to the operator, especially in narrow areas like the polpiteal fossa.

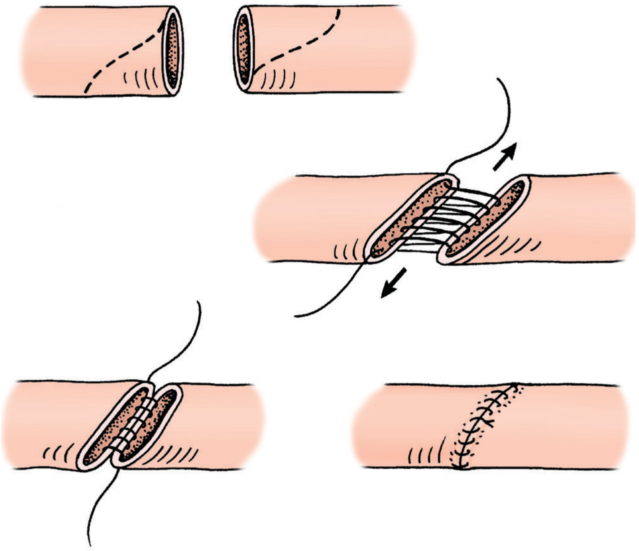

Figure 6.9 *When access or mobility is too poor for the technique illustrated in Figure 6.8, a running, posterior monofilament suture draws the ends together and is continued around the front of the vessel.*

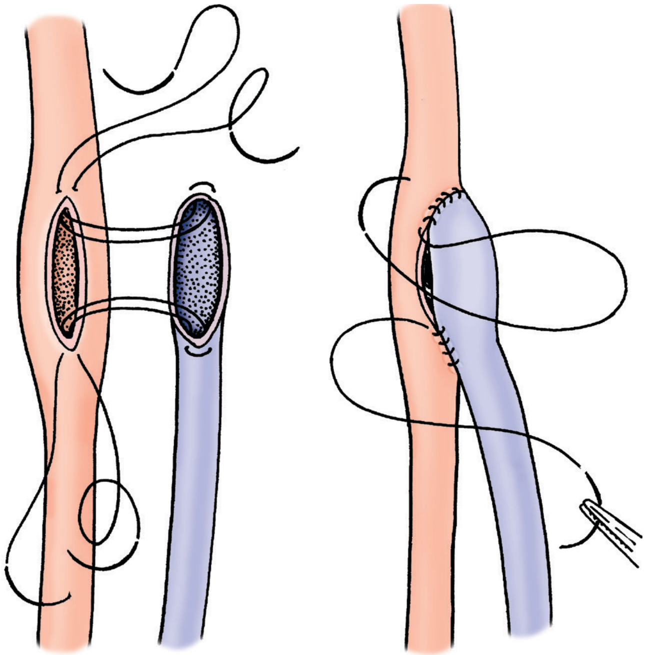

Figure 6.10 *The initial anchoring sutures have been placed at the heel and toe of the anastomosis between the native artery and the vein graft and as access is unrestricted, the remainder of the anastomosis will be completed from without.*

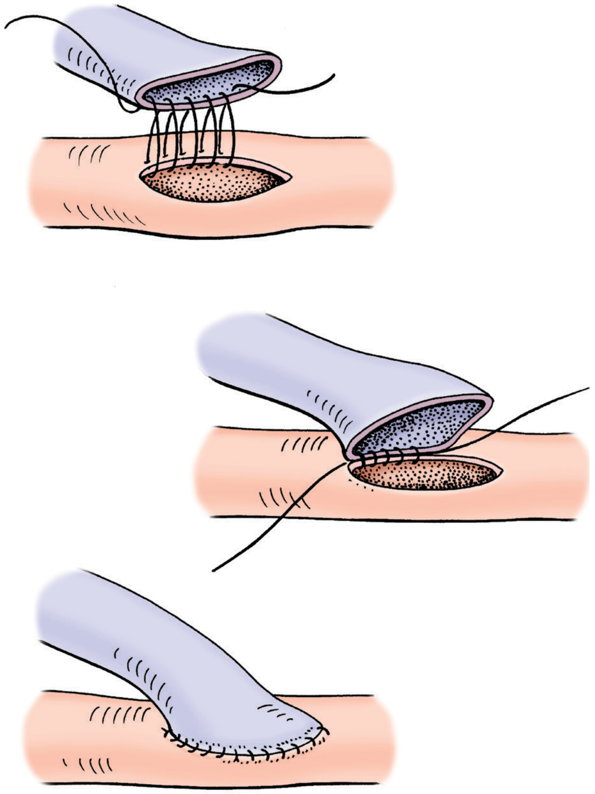

Figure 6.11 *When access is limited, the initial stitch with a double-ended suture should be at the heel, and the back of the anastomosis is completed from within in a similar fashion to that illustrated in Figure 6.9. The front of the anastomosis is performed from without and on completion the two ends of the suture are tied together.*

VASCULAR RECONSTRUCTION

Reconstruction with grafts may be required for a long congenital stenosis or for trauma where a segment of vessel wall has been lost or severely damaged. In these situations the surgeon is handling healthy artery above and below the area to be replaced. However, the commonest indication for reconstructive arterial surgery is degenerative arterial disease that has resulted in stenosis, occlusion or aneurysmal dilatation. The patient has generalised disease throughout the arterial tree. The arteries to which the surgeon anastomoses a graft are usually, to some degree at least, affected by the same process. More distant proximal and distal vessels may also be affected, compromising outflow and/or inflow. Additionally, the patient is at high risk of thrombotic complications, either locally or at a distant site. The latter may result in a myocardial infarct, stroke or renal dysfunction.

Arterial reconstruction for trauma is commonly by a replacement graft of vein or prosthetic material, which is used to bridge the defect between undamaged proximal and distal portions of the artery. Autologous vein is preferable if there has been penetrating trauma with inevitable contamination. Vein is ideally harvested from the contralateral limb in order to avoid exacerbating any co-existing venous compromise.

Vascular reconstruction for occlusive degenerative disease is more often by bypass graft. The native artery is left *in situ* and the graft is anastomosed end-to-side above and below the obstructed segment (Figure 6.12). Certain advantages are claimed over an end-to-end bypass technique: there is less potential for narrowing of the vessel at the anastomoses, dissection is minimised, collaterals are preserved and a graft need not follow the anatomical route of the native vessel. An alternative extra-anatomical route may be preferable or even essential. Sufficient inflow, good run-off into distal vessels and an adequate conduit are the prerequisites for success.

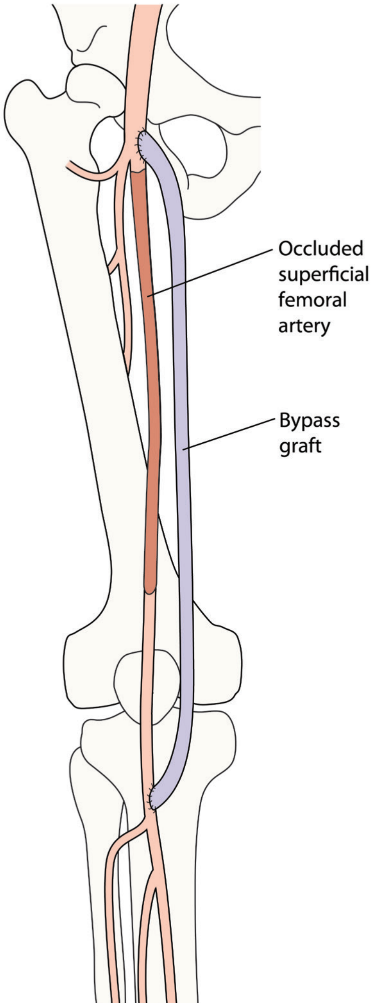

Figure 6.12 *A bypass graft with end-to-side anastomoses is frequently used for reconstruction in occlusive vascular disease. The diseased native vessel is left* in situ.

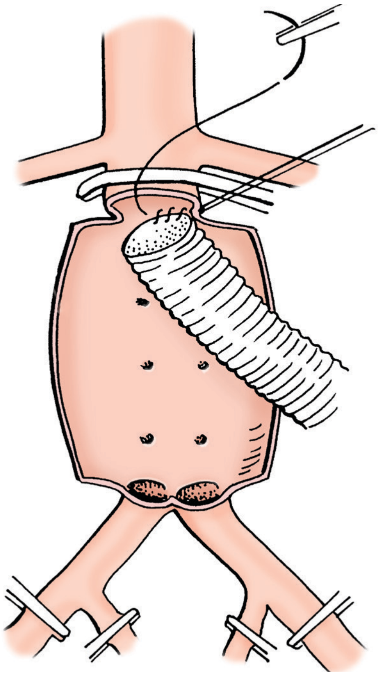

Figure 6.13 *An in-lay technique is suitable for graft replacement of an aortic aneurysm. The aneurysm is opened and the graft laid within it. The backs of both the proximal and the distal anastomoses are sutured from within.*

Vascular reconstruction for aortic aneurysmal disease is commonly with an in-lay technique. The aneurysm is opened and the graft placed within it. The anastomosis is end-to-end, but half of its circumference is sutured from within (Figure 6.13).

Venous reconstructive surgery has been disappointing in comparison with the results for arteries; the periods of low-velocity flow and of venous stasis in veins predispose to thrombus formation. Sophisticated techniques, sometimes involving the creation of a controlled arteriovenous fistula to increase flow, have been associated with more success and are discussed in Chapter 7.

Autologous vein

Autologous vein is the material of choice for reconstruction of small and medium-sized arteries. A successful vein graft quickly develops many of the characteristics of an artery. A normal LSV is the ideal substitute for an artery of comparable size. If the LSV is unavailable or diseased, superficial arm veins can be used as an alternative.

'Vein harvesting' must be meticulous to avoid unnecessary trauma to the vein, and is described in more detail in Chapter 7 (p. 131). If a vein graft is reversed, venous valves do not impede blood flow. If it is not reversed, the venous valves must be destroyed and this is also described in Chapter 7.

Prosthetic grafts

Prosthetic grafts are satisfactory for reconstruction and in current practice are generally used to replace the aortoiliac segment and for extra-anatomical bypass. They are also used for infrainguinal bypass, but the primary patency of prosthetic grafts is inferior to that of vein grafts when the graft has to be taken to a below-knee artery (infrageniculate bypass). Prosthetic grafts are more prone to thrombosis at low-flow velocities and, in addition, platelet adhesion is a greater problem than in vein grafts. This will occur especially where blood flow is turbulent, and the distal end-to-side configuration on a small vessel is particularly vulnerable. Cuffs and patches of vein have been incorporated into these distal anastomoses in an attempt to improve patency (Figure 6.14), and when insufficient vein is available for a complete bypass, a composite graft can be formed, reserving the vein for the distal portion, but this is considered a poor alternative by many surgeons. Prosthetic grafts do not become lined by endothelium, but a smooth luminal pseudointima develops consisting mainly of collagen. Wound infection may result in graft contamination. Autologous material has intrinsic resistance to infection and additionally is a site that can be reached by antimicrobials. Prosthetic graft infection is difficult to treat and can result in the need for early or late graft excision.

DACRON

Dacron™ has proved a durable replacement for the aorta and iliac vessels. It is less suitable for distal vessels as it becomes less flexible with time and damage to its structure may occur where it crosses joints. The inert polymer thread is woven or knitted to form a straight tube or bifurcated graft of varying sizes. Knitted grafts have the advantage of greater porosity,

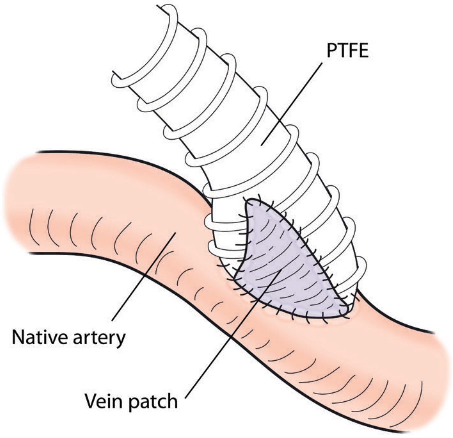

Figure 6.14 *Vein is the ideal graft material for distal reconstruction, but insufficient vein may be available. A cuff or a patch of vein incorporated into the anastomosis between the synthetic graft and the native vessel may improve long-term patency.*

which allows more in-growth of native tissue, and knitting means that the edges do not fray. In order to minimise excessive bleeding through the graft they have already been sealed during the manufacturing process with collagen, gelatin or albumin.

Dacron™ is also a suitable patch material when vein is unavailable. A small piece can be used as a buttress over which a suture is tied when suturing friable diseased arterial wall.

EXPANDED POLYTETRAFLUOROETHYLENE

e-PTFE retains flexibility and is preferred by some surgeons for infrainguinal bypass, although trials have shown little difference between the patency rates of e-PTFE and Dacron™. The material is in some ways non-compliant and stitch holes will leak. Small-diameter needles should therefore be used. It also has no longitudinal elasticity and tension must be avoided, in contrast to the technique with a vein graft where tortuosity is of greater concern.

Potential complications of vascular reconstruction

Assessment of flow at the end of any reconstructive procedure is important and on-table completion angiography is the ‘gold standard’. Failure of a graft in the first few hours is usually due to a technical failure that could have been detected before the wound was closed. The graft may be twisted or kinked, there may be a technical issue with the anastomosis or there may be residual undetected thrombus within either the graft itself or the run-off. Re-exploration is indicated except perhaps in cases where the surgeon felt the chances of failure were high at the time of surgery, usually due to poorer than expected run-off.

Failure of a vein or prosthetic graft may occur both early (within 30 days) or late as a result of thrombosis. Long-term patency of vein grafts is superior to that of prosthetic grafts. Late graft failure may be the result of progression of atherosclerotic disease compromising the inflow, the outflow or the graft itself (if vein has been used). Another potential threat to long-term graft patency is the process of ‘neo-intimal hyperplasia’, which is seen predominantly at areas of turbulent flow at the anastomoses. Effectively, this results in vessel wall thickening and graft stenosis. Aneurysmal degeneration can also occur, leading to sluggish flow, which predisposes to thrombosis or even rupture. Graft surveillance with duplex scanning is advocated to identify potentially correctable causes of late graft failure, including anastomotic narrowing, vein graft stenosis due to operative handling injury or patent venous tributaries forming fistulae. Typically, surveillance scans start at 6 weeks after surgery and are discontinued at a year, but only autologous grafts benefit from this kind of follow-up.

Infection is a major concern with prosthetic grafts, but less so with vein grafts. Once established, infection is very difficult to eradicate and usually heralds the loss of the graft. Grafts can be soaked in antibiotics (such as rifampicin) prior to implantation or impregnated with silver by the manufacturer; there is, however, only modest evidence to support either of these strategies. In contrast, prophylactic antibiotic cover is strongly evidence-based and is routine for all reconstructive vascular surgery.

Microvascular surgery

The development of microsurgical techniques has enabled surgeons to repair or anastomose vessels previously considered too small for this to be possible. Such work is mostly restricted to specialised plastic surgical units, where microsurgery has allowed the development of free tissue transfer. The small vessels of free flaps are anastomosed to vessels in the area where the flap is to be utilised (see Chapter 2). Microvascular surgery is also of value in trauma, where it allows the repair of small vessels, such as the digital arteries in a child.

ENDOVASCULAR INTERVENTION

Minimally-invasive endoluminal vascular interventions have found an increasing place in the management of vascular pathology. In the UK these techniques have generally been developed by interventional radiologists who work in collaboration with vascular surgeons; there is considerable cross-over between the disciplines. The most appropriate management for an individual patient will depend not only on the vascular lesion, but also on the patient’s overall condition and on the skills and facilities that are available.

A femoral artery approach is the most versatile for interventional procedures, but the brachial artery is an alternative. The *Seldinger* technique involves arterial puncture with a needle through which a wire is passed to allow safe and controlled catheter placement over the wire. Diagnostic and interventional procedures can then be undertaken through the catheter. A comprehensive description of different techniques, wires and catheter systems is outwith the scope of this text.[5]

ANGIOPLASTY

Transluminal angioplasty employs an inflated balloon to split the stenotic atheromatous plaque, thereby enlarging the lumen of the vessel at the target site. In general, this approach is more successful in short stenoses. Subintimal angioplasty involves the intentional creation of a false lumen, subintimally in the plane between the intima/atheroma and the outer layers. Long-term results of subintimal angioplasties for long strictures may be equivalent to surgical bypass with a prosthetic graft.[6] Angioplasty is also appropriate for fibromuscular stenoses. Radiological angioplasty now offers an alternative to open surgery at most sites. Venous angioplasty has a role in re-opening vessels compressed by tumour, for example in the superior vena cava syndrome, but it must be combined with a stent.

STENTS AND VENOUS FILTERS

Stents may be employed to maintain a lumen after angioplasty if there is arterial recoil or if a flow-limiting dissection has been created. Stents can also be employed across an area of partial traumatic disruption in the aorta or carotid vessels.[7,8] Intraluminal stenting of aortic aneurysms is now an established technique (see Chapter 7). Stents, introduced through the jugular or femoral vein, can maintain the lumen of an iliac vein or superior vena cava compressed by tumour. Treatment of chronic iliac vein thrombosis by venous angioplasty and stenting is possible and results are improved by the creation of a temporary arteriovenous fistula.

Inferior venal caval filters have proved effective in protecting against pulmonary embolism in patients with deep venous thromboses extending into the iliac segment.

THROMBOLYSIS

Thrombolysis may be an alternative to surgery in an acutely ischaemic limb, provided the limb is not so acutely threatened that any further delay would be critical to tissue survival. Although early experience with the technique used *streptokinase,* in contemporary practice *tissue plasminogen activator* (t-PA) is more widely used. The thrombolytic agent is delivered into the thrombus via a catheter with the tip placed at the proximal extent of the thrombus. A variety of regimes have been developed with slow infusion, pulsed-spray delivery and high-dose bolus infusion. In some methods there is a mechanical element to the clot disruption in addition to the pharmacological element. All techniques are labour intensive, requiring multiple angiograms and repositioning of catheters. However, results can be very good in selected cases. During treatment there is often an initial deterioration in perfusion as the clot fragments, and careful monitoring and pain relief are essential. The risk of iatrogenic bleeding with continuous lysis is a significant issue, both at the local puncture site and also remotely. Iatrogenic intracranial, intraocular, gastrointestinal or retroperitoneal bleeding can be catastrophic.

EMBOLISATION

The treatment of arteriovenous malformations and the control of inaccessible sites of bleeding are other areas where the interventional radiologist may be able to achieve better results than conventional surgery. A catheter is advanced into the vessel and flow may then be obliterated either mechanically (for example by deploying platinum coils) or pharmacologically (for example by instillation of absolute alcohol).

VASCULAR ACCESS SURGERY

Venous access

Peripheral venous access is almost universally established percutaneously, but a ‘cut-down’ procedure is occasionally necessary, as described in Appendix I. Central venous access is nearly always also possible percutaneously via an internal jugular or subclavian route (see also Appendix I), but cut-down techniques can still be useful.

The *cephalic vein* is exposed in the deltopectoral groove. It joins the axillary vein after piercing the clavipectoral fascia.

The *external jugular vein* can be exposed by an oblique incision lateral to the lateral edge of the sternocleidomastoid, 2 cm above the clavicle. A cannula can be directed through it into the internal jugular vein.

The *internal jugular vein* can also be cannulated directly using an open surgical approach. It lies immediately deep to the lower third of the sternocleidomastoid muscle and can be approached via a small transverse incision at the lateral border of the muscle, which is then retracted medially. The danger of air embolism must be remembered when the vein is entered.

Arteriovenous fistulae

The majority of patients in the UK requiring long-term haemodialysis do so on a background of chronic renal failure associated with the complications of metabolic, cardiovascular or autoimmune disease. The need for access can therefore often be predicted for many months before dialysis is required, allowing time for planning, creation and maturation of a fistula. There is little argument that an arteriovenous fistula is the optimal access for haemodialysis. The alternative tunnelled central venous catheter access has the not insignificant disadvantages of sepsis and central vein thrombosis.

The rules for arteriovenous fistula formation are simple; a non-dominant arm is preferable and the fistula should be created as distally as possible. Prosthetic material should only be used when other alternatives are impractical. Careful patient assessment and choice of procedure are the keys to success. Clinical assessment has a role, but this is augmented by duplex imaging and occasionally by venography. Three specific aspects need to be considered:

- Inflow may be compromised by arterial disease, with subsequent failure of the fistula to mature.
- Distal arterial disease, particularly in diabetic patients, can result in a ‘steal syndrome’, with worsening distal ischaemia.
- Superficial veins may have been damaged by phlebotomy and cannulation, and deep veins may be stenosed or occluded by central venous catheterisation.

Procedures can be performed under local, regional or general anaesthesia. An appropriate incision is made to facilitate mobilisation of the target vessels. For example, at wrist level, a longitudinal incision, halfway between the radial artery and distal cephalic vein, will allow both vessels to be mobilised. Here, with the vessels lying adjacent, a longitudinal arteriotomy and venotomy can be followed by a side-to-side anastomosis using 6/0 monofilament suture material. There is a variety of different techniques for creating fistulae in different locations and often an end-to-side anastomosis of the divided and mobilised proximal end of the vein onto the artery is necessary. On completion it is prudent to ensure that there has been no compromise of distal perfusion and that there is flow through the fistula and a palpable thrill. Thereafter, it is a case of allowing the fistula to mature, although a proportion will fail to do so. However, a fistula that has failed to mature is not necessarily a disaster, as the more proximal veins will often have 'arterialised' to some extent, which may increase the chance of success in the future.

Alternative upper limb techniques, in the face of an unsuitable, absent or damaged cephalic system include:

- Basilic vein mobilisation, distal disconnection and transposition so that it can be anastomosed to the brachial artery.
- Upper limb loop fistula using either LSV (Figure 6.15) or e-PTFE.

When upper limb access has been exhausted, lower limb access should be considered. The most commonly adopted strategy in the lower limb is the creation of a thigh loop fistula with either LSV or e-PTFE.

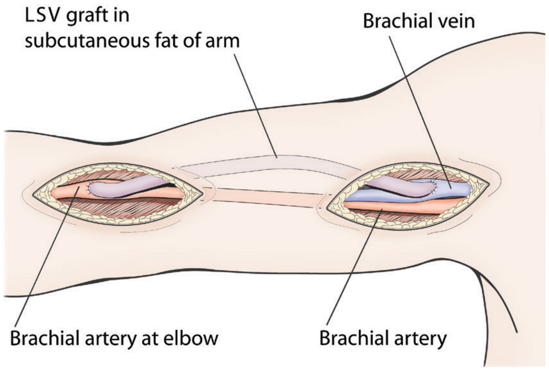

Figure 6.15 *A subcutaneous loop arteriovenous fistula has been created between the brachial artery and the brachial vein.*

VASCULAR TRAUMA

The proportion of a surgeon's vascular work that is related to trauma is extremely variable. Penetrating vascular injury is common in conflict zones and is also frequent where there is a high level of urban violence. In many of these scenarios the conditions for complex vascular surgery are suboptimal, and the management of the vascular injuries will have to be tailored to the level of surgical and support facilities available and the vascular experience of the surgeon. In the UK, most penetrating vascular injuries are iatrogenic.

Iatrogenic vascular injuries

Vascular injuries that occur during open surgery are normally immediately obvious due to haemorrhage. Many are clean arterial incisions or defects created by vessel avulsions that can be closed as an arteriotomy, once control has been achieved. Injuries to large veins can be repaired in a similar fashion, but it is often more appropriate simply to ligate smaller veins. Iatrogenic injuries to the aortoiliac vessels are seen relating to the initial entry into the peritoneal cavity with a Veress needle at the start of laparoscopic surgery. These injuries may extend through the back wall of the vessel, and it is important to mobilise the vessel sufficiently so that the posterior wall can be inspected and repaired. On occasion this repair needs to be done from the inside of the vessel (e.g. posterior wall injuries to the aorta).

Cannulation injury to an artery at angiography usually seals and heals uneventfully. However, a *false aneurysm* can develop after any form of arterial cannulation. If distal flow is not compromised, open intervention can often be avoided. Duplex scanning can confirm the diagnosis and local, directed pressure with the ultrasound probe for 15–20 minutes may then induce thrombosis within the aneurysm. An alternative strategy is injection of thrombin under ultrasound guidance. More significant cannulation injuries, such as those with a broad neck to a large pseudoaneurysm or where there is active bleeding, often require surgery. The high mortality in patients who require surgical intervention is partly explained by associated co-morbidity, often the indication for the intervention in the first place. In the upper limb, although false aneurysms may be encountered, cannulation injuries more frequently result in thrombosis and occlusion. The forearm is not always threatened by critical ischaemia as there is a good collateral blood flow around the elbow. However, long-term symptoms of forearm muscle fatigue may be troublesome and, if forearm muscle ischaemia is more severe, a Volkman's contracture may ensue despite adequate finger-tip perfusion. Because of this, a brachial artery occluded following puncture should not be ignored even if the hand appears viable. A balloon thrombectomy will usually restore flow and a formal repair of the underlying injury can then be undertaken. This will usually be the repair of an intimal flap. As always, the general condition of the patient influences decisions around intervention.

Non-iatrogenic trauma

The vascular damage in *penetrating trauma* can vary from a clean incision with a sharp blade to extensive destruction from a high-velocity bullet injury (see Chapter 4). Vascular injury can also occur in *blunt trauma*. A spicule of fractured bone may lacerate a vessel or a crushing, shearing or stretching force may contuse or tear the vessel wall. An adventitial haematoma from a crushing injury can be relatively harmless, but an intimal split, common with a shearing or stretching injury, predisposes to the formation of secondary thrombus or dissection of the arterial wall. Distal blood flow may be satisfactory on initial examination, but subsequently lost as thrombosis or dissection develops at the site of injury. If both the intima and media tear, vessel integrity may be maintained by the adventitia alone; delayed rupture, or occasionally late aneurysmal dilatation, can then occur. It is always important to document clearly the distribution of distal pulses and the sensorimotor function of the limbs. Any changes should be taken seriously. A high level of vigilance for deterioration and a low threshold for requesting (further) imaging should be maintained.

Exploration of an artery

The decision to explore an artery is straightforward if there is an overlying wound with profuse arterial bleeding and/or obvious distal ischaemia. However, the decision becomes more difficult if the bleeding appears to have stopped and the access to the area of concern is difficult. An arteriogram is invaluable in these circumstances and should be performed if possible. In the context of the haemodynamically stable patient with multiple injuries, intravenous contrast CT performed in the arterial phase should be requested along with CT assessment for other injuries.

Access to explore an injured artery is often a modification of a standard approach, influenced by the wound already present, but vessel control must always precede direct dissection of the site of haemorrhage. If there is profuse haemorrhage, this must be controlled with local pressure until the vessel has been mobilised sufficiently to gain proximal and distal control. Sometimes, initial temporary control, which can be later revised, must be gained significantly proximal to the injury. Brisk bleeding usually indicates a partially severed artery that is unable to contract. A completely severed artery will often close with intense spasm; the contracted ends are found lying within a haematoma. Ideally, the proximal and distal tapes should be in position before any arterial haematoma is explored.

'Arterial spasm' associated with an injury is an unsafe explanation for poor distal perfusion. If good distal flow is not restored within 2–3 hours, the artery must be explored or imaged. Discontinuity on an angiogram is not usually spasm. When an apparently intact, but contracted artery is found at exploration it should be viewed with great suspicion. There is almost certainly an underlying intimal injury and the spasm is secondary to this. The use of a hand-held Doppler device wrapped in a sterile glove and a laparoscopic camera drape is a useful aid to decision making. Application of local vasodilator drugs may abolish the spasm and temporarily restore some distal flow, but this should not necessarily reassure the surgeon that there is no significant damage. Deterioration may occur again later as the distal edge of an intimal tear lifts to initiate a dissection or rolls up to form a partially occluding flap on which thrombus develops. When an intact, but contracted and contused artery is found it must be explored unless angiography or a Doppler scan has been entirely reassuring. The damage will be at the proximal end of the contracted segment. The damaged section of artery at the junction between the normal and contracted segments should be excised and continuity restored. In most situations a short venous bridging graft will be necessary.

Sometimes, exploration reveals a large expansile haematoma or false aneurysm, associated with a small arterial wound. The haematoma should be evacuated and the artery repaired. Operating on young people is difficult. The vessels are very prone to spasm and even short interposition grafts may not 'run'. Stripping back the adventitia on both the native artery and the vein graft helps. If the injury has occurred after exercise, whether sport, combat or flight from danger, the metabolic changes within the ischaemic limb are greatly accelerated and a shunt should be considered early.

When in doubt, the options of on-table angiography and radiological intervention should always be remembered.

SIMPLE LIGATION

Simple ligation of a damaged artery is always an alternative to repair, and is occasionally the only solution even for proximal arterial injuries in combat conditions. The vessel is ideally ligated at the site of injury, but occasionally only a more proximal ligation is practical because of difficult access. However, any arterial injury at or above the elbow or knee should be repaired or reconstructed if at all possible, as simple ligation at this level risks significant ischaemia even if the limb remains viable. (The subclavian and superficial femoral arteries constitute exceptions to this general rule, as good distal perfusion is maintained by collaterals.) Repair or reconstruction of arteries below the knee or elbow is desirable, but only necessary if more than one main artery is injured or when there is compromised tissue perfusion as a result of anatomical or pathological variations in arterial arcades.

Intravenous drug abuse is associated with multiple punctures of both veins and arteries in the groin and antecubital fossa. Arteries are damaged both by mechanical trauma to the vessel wall and by repeated infections. Surgical intervention may be necessary for bleeding or for an expanding pseudoaneurysm. Ligation is indicated as reconstruction in these circumstances is extremely difficult. Fortunately, the vessel has usually been damaged so many times that the collaterals are well developed.[9]

ARTERIAL REPAIR AND RECONSTRUCTION

The first priority is to re-establish inflow and outflow and then protect this with local heparinisation of the vessels. Gentle use of a Fogarty catheter, supplemented by on-table angiography if necessary, achieves this essential step. A clean incision in a large artery can be sutured without narrowing the lumen, but it is often necessary to use a vein patch if the artery is small but vital, or when contused edges of the arterial injury require excision. A completely severed artery can occasionally be repaired by direct end-to-end apposition if minimal trimming is required and there is no tension. However, severed vessels tend to retract and the ends become spastic, so more often a short interposition vein graft is required, especially if contused vessel wall adjacent to the injury has been excised. The proximal end-to-end anastomosis is completed and the graft allowed to fill. The vein graft is then cut to the appropriate length and the distal anastomosis performed. If access to the injury is difficult, simple ligation followed by a bypass graft is an alternative. Prosthetic patches and grafts should be avoided in penetrating trauma as the operative field will be contaminated.

The most frequent repair is a simple closure of a groin puncture site after an endovascular cannulation, either investigative or therapeutic. The cannula has often been inserted into a diseased portion of the common or superficial femoral artery or into the common femoral bifurcation. In these circumstances the puncture wound is held open and the bleeding is resistant to pressure. A vertical groin incision will usually afford adequate access. The common femoral artery is controlled with a vascular clamp immediately below the inguinal ligament. However, this may not be possible or the bleeding may be coming from a puncture deep to the inguinal ligament or above it. In these circumstances the external iliac artery must be clamped (see below). Access is through an oblique iliac fossa incision; the patient should always be prepared so that this is possible.

VENOUS REPAIR AND RECONSTRUCTION

Venous trauma can be extremely difficult to deal with. Once a tear starts it will extend quickly with minimal force and a long rent in a major vein will bleed profusely. The flow is constant and pools at the site of injury, in contrast to the bleeding from the equivalent artery, which is pulsatile and projected away from the bleeding site. The major veins in the trunk often have no valves and blood will flow from both directions.

Most venous trauma is iatrogenic and occurs during surgery. The simplest way to stop the bleeding is by local pressure, then packing and positioning the patient head down. This will not only slow or stop the bleeding but also serve to alert the rest of the theatre team that there is a problem. Blind clamping will make things worse both immediately and later due to collateral damage. Time should be taken to ensure adequate lighting, optimise patient position, set up suction, summon assistance and allow the anaesthetist to prepare for major fluid shifts and significant haemorrhage. Once everything is optimised, the bleeding site is carefully unpacked. Remember, the goals are exposure and control. A tiny avulsed tributary can leave a long tear in a major vessel such as the common femoral vein or the inferior vena cava (IVC). Identifying the vessel that is bleeding is the first task. This is not the same as dissecting the actual site of bleeding. Control above and below the site of bleeding either formally with slings or with simple pressure will usually reduce the flow to a trickle.

The most helpful first step in the repair of a venous laceration is to place the first suture just beyond one end of the tear. This anchor point gives significant control and the operator can then advance one stitch at a time along the tear, exposing the vein a little at a time. Sometimes, the biggest challenge is access. An iliac vein tear may require division of the iliac artery to gain control. Access to the cava may require mobilisation of the duodeneum or kidney. However, before embarking on these heroic steps, simple packing followed by a night in intensive care with warming and correction of clotting defects should be considered. The next visit to theatre is often a simple process of removing packs and resisting the temptation to disturb the depths of the wound. Iatrogenic bleeding in the pelvis is a situation where packing and waiting is often the best option by far.

In major limb trauma, while more extensive repair or reconstruction is advisable when major axial veins (e.g. the femoral) are damaged, distal veins are more appropriately treated by ligation except in the ‘near-amputation’ situation, when the restoration of venous drainage, in addition to arterial reconstruction, improves outcome.[1,3] Two veins should be rejoined for each artery. An oblique end-to-end technique with interrupted sutures is recommended.

EXPOSURE OF THE MAIN VESSELS OF THE TRUNK AND LIMBS

The surgical anatomy of the main vessels of the trunk and limbs is discussed below, with particular emphasis on the dissection required for exposure and control in trauma. However, the commonest indication for exposure of a main artery is for reconstruction of vessels damaged by chronic arterial disease. These elective operations are described and their indications discussed in more detail in Chapter 7.

The intrathoracic aorta and great vessels of the superior mediastinum

Elective surgery of these vessels is now undertaken almost exclusively in cardiothoracic units, to which all patients will be referred. If it is possible to stabilise a patient for transfer in an emergency scenario, this will also be in the patient’s best interests. Those with trauma to the aortic arch or the origin of its main branches will probably require cross-clamping of the aorta and cardiopulmonary bypass for a successful repair. The side occlusion of the aorta for repair shown in Figure 6.2b, although suitable for an elective endarterectomy, is usually impractical in trauma owing to haematoma and distortion of the anatomy. Aortic transection beyond the subclavian may be repaired wihout cardiopulmonary bypass, but the high aortic cross-clamping is associated with major difficulties. These injuries may be best treated by endovascular techniques.[7] A general or vascular surgeon will therefore only have to manage patients who are too unstable for transfer to a cardiothoracic unit and are usually also too unstable for any preoperative imaging or endovascular intervention. A clamshell incision, as discussed in Chapter 8, is suitable. The alternative median sternotomy can be extended upwards along the anterior border of sternocleidomastoid for more extensive access to the carotid vessels, or laterally above the clavicle for the subclavian vessels (see Figure 10.4, p. 167). However, a median sternotomy is a more difficult incision in an extreme emergency outside a cardiothoracic theatre. The descending thoracic aorta is exposed through a left lateral thoracotomy.

The carotid arteries

Carotid artery injury is of major concern in trauma to the neck. Management of overt or suspected carotid artery injury is discussed in Chapter 10. Uncontrollable haemorrhage into a severely damaged face, maxillary antrum or larynx can be life threatening. An interventional radiologist may be able to embolise the bleeding vessels but alternatively, ligation of the external carotid artery (ECA) on the side of the injury can be life saving. The carotid bifurcation must be carefully dissected to identify beyond doubt that the correct vessel is ligated. Always remember that the internal carotid artery (ICA) has no extracranial branches; unintended ligation of the ICA in a young patient will result in a stroke on more than 50 per cent of occasions. Endarterectomy for the prevention of stroke is the most commonly performed elective vascular operation in the neck and is described in Chapter 7.

ANATOMY

The *common carotid artery* begins its course in the neck behind the sternoclavicular joint. Thence, it passes upwards, deep to the sternocleidomastoid muscle, towards the lobe of the ear. It ends in a bifurcation, usually opposite the upper border of the thyroid cartilage, forming the ECA and the ICA. The common carotid artery is enclosed, along with the internal jugular vein and the vagus nerve, in the carotid sheath of deep cervical fascia; the vein is lateral to it and the nerve lies posteriorly in the groove behind the two vessels. The ECA runs upwards from the carotid bifurcation to end behind the mandible, by dividing into its terminal maxillary and superficial temporal branches. The ECA leaves the carotid triangle by passing under cover of the posterior belly of the digastric muscle, and its upper part occupies a groove on the deep surface of the parotid gland or lies within the gland. It is the major vascular supply to the neck, face and scalp. There are three large anterior branches: the superior thyroid, the lingual and the facial. The occipital and posterior auricular are posterior branches. The ICA ascends from the carotid bifurcation to enter the skull through the carotid canal, just posteromedial to the temporomandibular joint. It is at first posterolateral to the ECA and then deep to it. It is enclosed in the carotid sheath, with the internal jugular vein laterally, and with the vagus nerve deep in the space between them; at the skull base the vein is posterior to the artery. There are no branches in the neck and it supplies purely intracranial structures.

EXPOSURE

In penetrating trauma, general anaesthesia with control of the airway is important. The head is turned to the opposite side and the neck slightly extended. This can be achieved by replacing the pillow with a 'head ring' and lowering the 'head' of the operating table or by placing a sandbag between the shoulder blades. The ideal cosmetic incision is in a skin crease, but the best exposure of the carotid vessels in an emergency is through a long oblique incision along the anterior border of sternocleidomastoid. In order to avoid damage to the cervical branch of the facial nerve, the upper end of the incision should not approach nearer than 1.5 cm to the angle of the mandible. Platysma and deep fascia are divided in line with the skin incision, and the external jugular vein is ligated and divided.

The anterior border of sternocleidomastoid is freed and the muscle retracted posteriorly. The common facial vein lies superficial to the common carotid artery and crosses it just below the bifurcation (Figure 6.16). This is ligated and divided, after which the internal jugular vein can be displaced

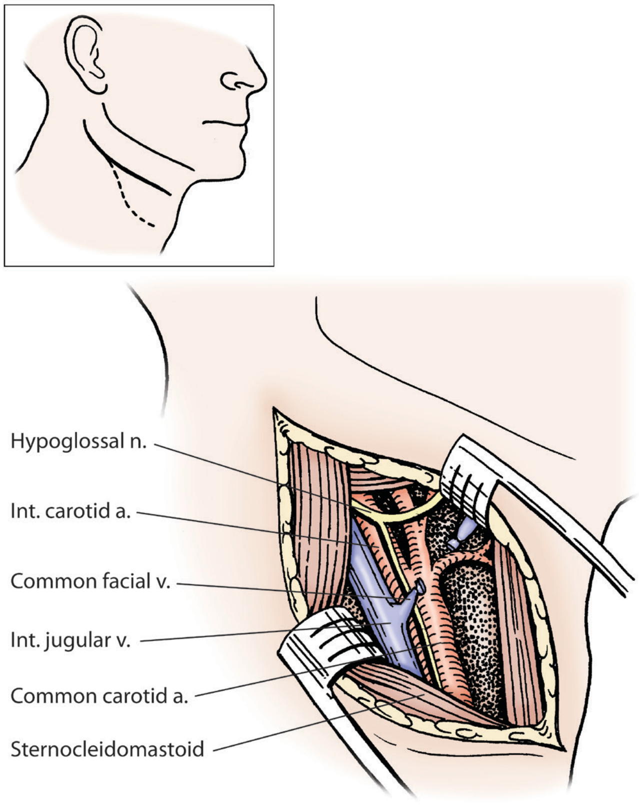

Figure 6.16 *An oblique incision along the anterior border of sternocleidomastoid gives better carotid access than the transverse incisions shown in the inset. The sternocleidomastoid muscle is retracted posteriorly and the common facial vein divided to display the carotid bifurcation.*

backwards to expose the carotid arteries more fully. The descending branch of the hypoglossal nerve is visible on the surface of the carotid artery. It can usually be preserved, but little harm ensues from sacrificing it if necessary. The main hypoglossal nerve crosses superficial to the carotid arteries, just above the bifurcation, and should be preserved. At the upper extremity of the dissection the carotids lie deep to the parotid gland and the posterior belly of digastric; access to this area in an emergency is more difficult.

The vulnerability of the cerebral cortex to ischaemia must be remembered and consideration given to the use of a temporary shunt. Repair of a carotid laceration will usually require a vein patch to avoid stenosis. A severely damaged ECA can be simply ligated, but the common carotid artery or ICA should be repaired or reconstructed as discussed in Chapter 10.

Subclavian and axillary arteries

Whereas limited exposure of these arteries may be sufficient for elective reconstructive arterial surgery, a more extensive exposure is usually necessary in trauma. Adjacent veins and nerves may also be damaged, and it is difficult to gain safe proximal and distal control amongst other vital structures when the anatomy is distorted by haematoma. Experience with these injuries has been acquired where there is a high incidence of urban violence.[10]

ANATOMY

The *subclavian artery* crosses the front of the cervical pleura at the root of the neck. It arches from behind the sternoclavicular joint to the outer border of the first rib, where it becomes the axillary artery. It rises to a level of 1–2 cm above the clavicle when the shoulder is depressed. Scalenus anterior crosses anterior to the artery. The first part of the artery is defined as the portion that lies medial to scalenus anterior; the second part lies behind this muscle and the third part lateral to it. The subclavian vein lies in front of scalenus anterior, at a lower level than the artery, and behind the clavicle.

The *axillary artery* runs downwards and laterally behind the clavicle into the roof of the axilla, and continues as the brachial artery at the lateral border of the axilla. The axillary artery is divided into three parts by pectoralis minor, which crosses anterior to the second part. The axillary vein lies just below and medial to the artery throughout its course, and the brachial plexus lies in close association with the artery.

EXPOSURE

The *third part of the subclavian* artery is the most surgically accessible. In trauma, when extensive exposure of the artery is required, the third part is often exposed initially and then the incision is extended medially. A limited exposure of the third part of the subclavian artery is occasionally indicated when there is uncontrollable haemorrhage from the axillary artery. A temporary clamp on the subclavian artery will then provide some proximal control during exploration of the axilla. Ideally, the damaged axillary artery is then repaired or reconstructed, but simple ligation of the third part of the subclavian artery is another possibility. Perfusion of the upper limb is safeguarded by an anastomosis around the shoulder, which is fed by branches arising from the proximal subclavian artery.

The arm is placed at the side and drawn downwards in order to depress the shoulder; the head is turned to the opposite side. An incision is made 1–2 cm above the clavicle from the sternal head of sternocleidomastoid to the anterior border of trapezius (Figure 6.17). The superficial fascia and platysma are incised in the same line and the deep fascia divided. The external jugular vein may cross the operative field and have to be divided between ligatures. A supraclavicular nerve may also have to be sacrificed. Omohyoid is retracted upwards and the third part of the subclavian artery is now exposed, with the upper and middle trunks of the brachial plexus lying superolaterally. The suprascapular artery, which arises from the thyrocervical branch of the first part of the subclavian artery, crosses the operative field as it runs superolaterally, anterior to the subclavian artery, with its accompanying vein and nerve.

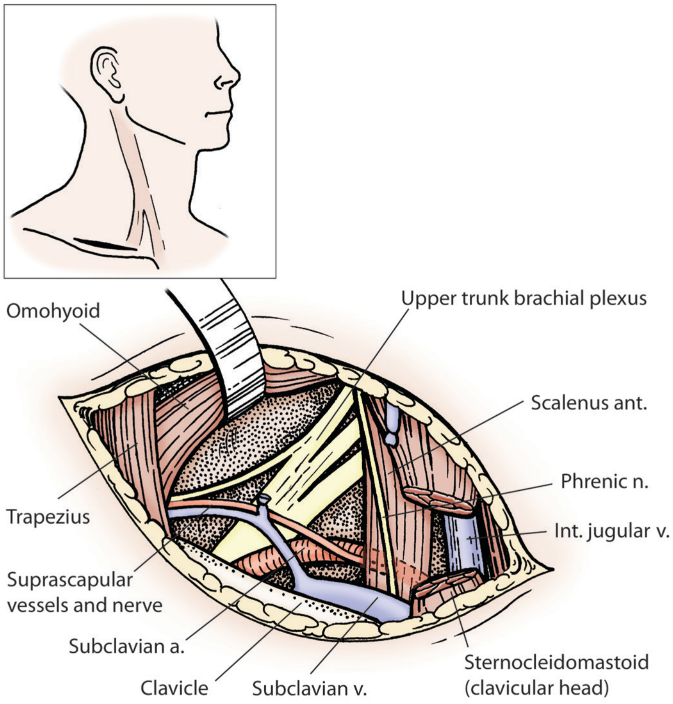
Omohyoid
Upper trunk brachial plexus
Scalenus ant.
Phrenic n.
Int. jugular v.
Trapezius
Suprascapular vessels and nerve
Subclavian a.
Clavicle
Subclavian v.
Sternocleidomastoid (clavicular head)

Figure 6.17 *The incision for exposure of the subclavian artery is above and parallel to the clavicle. Omohyoid is retracted and the subclavian artery is visible between scalenus anterior and the brachial plexus. Division of scalenus anterior and medial retraction of the internal jugular vein exposes the proximal subclavian artery. When more extensive exposure of the vascular root is required, the internal jugular can be retracted laterally or the incision can even be extended to combine it with a median sternotomy.*

Exposure of the *first and second parts of the subclavian artery* requires division of the clavicular head of sternocleidomastoid and division of scalenus anterior, followed by medial retraction of the internal jugular vein. The phrenic nerve lying on the surface of scalenus anterior should be preserved and held in a sling to retract it out of the operative field. The common carotid artery is obscured by the internal jugular vein. Lateral retraction of the vein exposes the common carotid artery and, with both arteries in the operative field, a carotid–subclavian bypass graft is possible through this approach.

In the past, this was a standard approach for cervical sympathectomy, but has now been generally superseded by minimal-access intrathoracic techniques (see Chapter 4). The artery can either be depressed downwards or gently mobilised and retracted upwards by means of a tape passed around it. The suprapleural membrane is detached from the inner border of the first rib, and the pleura is displaced downwards and laterally to expose the neck of the ribs with the sympathetic chain and ganglia.

The supraclavicular incision can be combined with a median sternotomy, in which case the sternal head of sternocleidomastoid is also divided (see Figure 10.4a, p. 167). This gives the extensive exposure necessary to gain control of the proximal subclavian or the brachiocephalic trunk in major trauma (see Chapters 8 and 10).

Axillary artery exposure is easiest with the upper limb partially abducted and supported on an arm board. The incision for an extensive exposure is along the deltopectoral groove from the lower border of the clavicle to the lower border of the anterior axillary fold (Figure 6.18). Anterior branches of the axillary artery and the termination of the cephalic vein will be encountered. The cords of the brachial plexus lie around the artery and the axillary vein lies inferomedially. The tendon of pectoralis minor is divided. This incision can be extended downwards to expose the brachial artery (Figure 6.19). The incision can also be extended proximally to join with a supraclavicular incision and provide extensive simultaneous access to both the subclavian and the axillary arteries. The clavicle crosses the operative field, but can often be left intact. However, the root of the neck is a hazardous area for an inexperienced surgeon. The subclavian artery is relatively thin walled and bleeding from this artery or from one of the great veins is very difficult to control. In emergency situations, when rapid control of both the third part of the subclavian and the first part of the axillary artery may be essential, there should be no hesitation in dividing pectoral muscles and resecting the middle third of the clavicle.

A more limited exposure of the axillary artery, as may be required for an elective bypass graft, is described in the section on axillofemoral grafts in Chapter 7. A transverse transaxillary approach to the axillary artery as it crosses the first rib is used in the treatment of thoracic outlet syndrome (see also Chapter 7). The rib can be resected through this incision and the artery released. Access to the artery is, however, very limited and it is an unsuitable approach for trauma or for any reconstructive procedure.

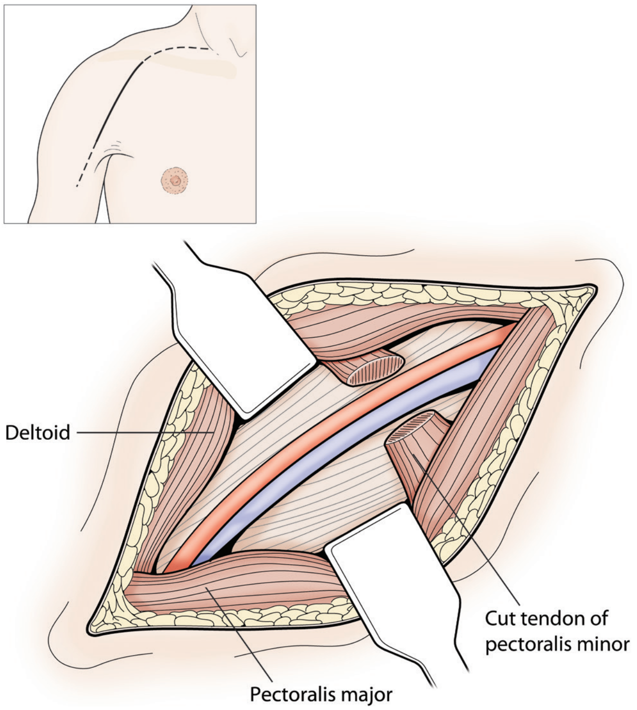

Figure 6.18 *The axillary artery is approached via an incision along the deltopectoral groove. It can be extended proximally if simultaneous access to the subclavian artery is required or distally to expose the brachial artery. Division of pectoralis minor and retraction of pectoralis major and deltoid exposes the artery.*

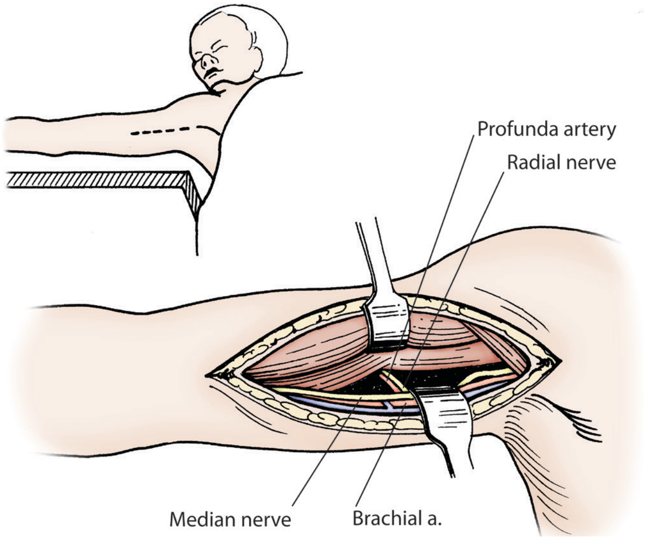

Figure 6.19 *Exposure of the brachial artery in the right upper arm.*

Brachial artery

The brachial artery may be approached with ease throughout its relatively superficial course. Exploration is most likely to be required for embolism or for a cannulation injury. Exposure may also be necessary to investigate possible damage associated with a fracture of the humerus or penetrating trauma.

ANATOMY

The brachial artery is the continuation of the axillary artery from the level of the lower border of teres major. It runs inferiorly and slightly laterally, at first medial and then anterior to the humerus. It ends at a bifurcation in the cubital fossa, at the level of the neck of the radius, by dividing into radial and ulnar arteries. The artery is accompanied by venae comitantes in its lower part and by the basilic vein in the upper part.

In *the arm*, the median nerve is initially lateral to the brachial artery but then crosses in front of the middle third of the artery to run along its medial side. The ulnar nerve is on the medial side of the artery in its upper half, but diverges from its lower half to run behind the medial epicondyle of the humerus. The median cutaneous nerve of the forearm also lies to its medial side in the upper half of the arm. At the *front of the elbow* the brachial artery enters the cubital fossa, with the tendon of biceps on its lateral side and the median nerve on its medial side. The artery and nerve are deep to the deep fascia and the bicipital aponeurosis, which stretches from the tendon of biceps to blend with the deep fascia over the medial side of the forearm.

EXPOSURE

In *the arm*, exposure is by an incision along the medial edge of biceps. The arm is abducted and rotated laterally and supported on an arm board (Figure 6.19). There may be a case for leaving the arm entirely free, supporting the limb only at the shoulder and the elbow, as arm support displaces the muscles and renders the approach more difficult. The deep fascia is divided along the same line, and care is taken to avoid the basilic vein, which pierces the deep fascia in this vicinity. The biceps is mobilised and drawn laterally to expose the artery and the median nerve. For *exposure at the elbow*, the arm is abducted, externally rotated and supported on an arm board. The deep fascia (including the bicipital aponeurosis) is incised vertically and the bicipital tendon retracted laterally. This is illustrated in Figure 6.20 for the *left* arm. However, the vertical skin incision shown, across the flexor aspect of the joint, should be avoided by making a transverse cubital fossa skin crease incision, enlarged by vertical extensions up from the medial end and down from the lateral end.

The abdominal aorta, renal vessels and inferior vena cava

The abdominal aorta and iliac arteries are frequently involved in atherosclerotic degenerative pathology. An approach to these arteries is required for reconstructive arterial surgery and described further in Chapter 7. However, the spontaneous rupture of an abdominal aortic or iliac aneurysm, or trauma that involves any of the major abdominal vessels, necessitates emergency access for the control of exsanguinating haemorrhage.

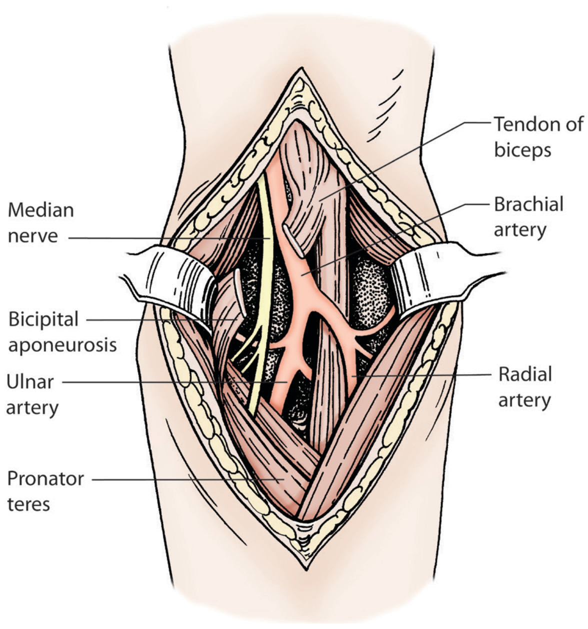

Figure 6.20 *Exposure of the brachial artery in the left cubital fossa.*

ANATOMY

The *abdominal aorta* enters the abdomen between the crura of the diaphragm, as a direct continuation of the descending thoracic aorta. It ends on the front of the body of the 4th lumbar vertebra, to the left of the midline, dividing into right and left common iliac arteries (Figure 6.21).

The *inferior vena cava* (IVC) lies along the right side of the aorta until it diverges to the right and is separated from it by the right crus of the diaphragm.

EXPOSURE

The upper abdominal aorta is not easily accessed by an anterior approach. There are only a few centimetres of unexposed aorta above the pancreas and the coeliac trunk arises from this short segment. The pancreas the splenic vein, the left renal vein and the third part of the duodenum all cross in front of the upper abdominal aorta and are closely applied to it. Three large arterial branches arise from the retropancreatic aorta; the superior mesenteric artery arises from its anterior aspect and the renal arteries from the lateral aspects. The origins of these major arteries also restrict mobilisation of the upper part of the abdominal aorta. The infrarenal aorta is more accessible, having only the preaortic nerve plexus and lymphatic channels over its anterior surface, and the only significant branches are the inferior mesenteric, lumbar and gonadal arteries.

Fortunately, for most reconstructive aortoiliac surgery, infrarenal aortic access is sufficient as the upper abdominal aorta is relatively spared degenerative pathology. The transperitoneal and the less common retroperitoneal approaches

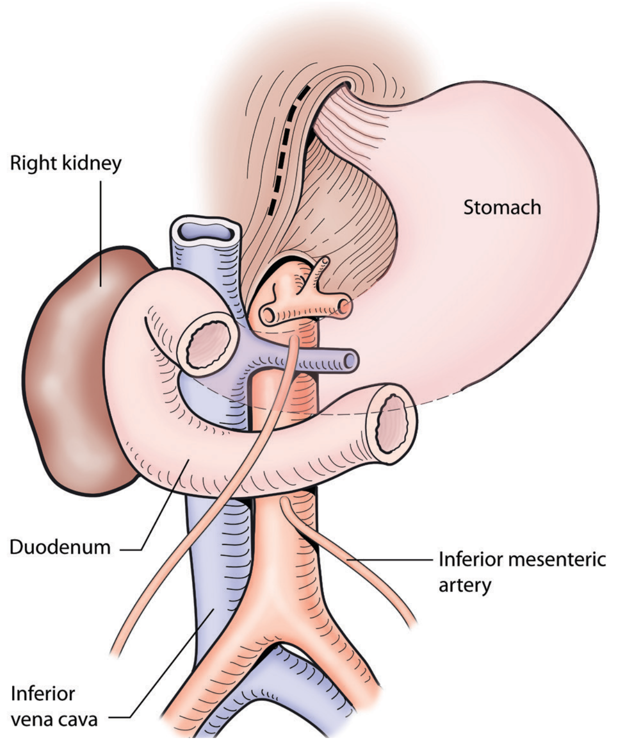

Figure 6.21 *In the upper abdomen the aorta is relatively inaccessible. Tributaries of the inferior vena cava (IVC) cross it anteriorly, whereas more distally the iliac arteries lie anterior to the veins. The retroperitoneal duodenum and pancreas also impair access. A vertical incision in the posterior parietal peritoneum, lateral to the duodenum, enables the surgeon to mobilise the second or fourth part of the duodenum off the IVC or aorta, respectively. A vertical incision in the right diaphragmatic crus exposes sufficient supracoeliac aorta for the application of a temporary occlusion clamp. When more extensive exposure of the proximal abdominal aorta or IVC is required, a medial visceral rotation manoeuvre may be indicated.*

for this surgery are discussed in Chapter 7. Proximal aortic control may be necessary in trauma or for an extensive aneurysm. The supracoeliac aorta can be exposed by opening the lesser sac through the lesser omentum. A vertical incision is then made in the right crus of the diaphragm, as marked in Figure 6.21. The distal extremity of the descending thoracic aorta lies immediately deep to the crus and sufficient access can be gained for proximal control. A finger is passed either side of the aorta and a vascular clamp applied. The fibres of either crus of the diaphragm can slip between the clamp and the aorta, creating an unstable clamp position or inadequate occlusion, clearly a problem in an emergency. A supracoeliac clamp renders both kidneys and the entire bowel ischaemic and is therefore only a temporary solution unless a shunt is employed to restore distal perfusion. Safe ischaemic time for the kidneys can be extended by renal cooling (see Chapter 26).

The thoracic aorta can also be cross-clamped at an initial 'emergency room' left thoracotomy (see Chapter 8). This manoeuvre is associated with significant morbidity and is therefore reserved for occasions when the supracoeliac abdominal aorta is not accessible or if there is doubt as to whether the bleeding is from above or below the diaphragm.

When more extensive upper abdominal aortic access is required – and in particular when there is a posterior penetrating injury – a left-sided medial visceral rotation may be necessary. The plane is entered lateral to the spleen and the dissection carried medially behind the spleen, kidney and pancreas to lift all the viscera off the retroperitoneal structures. This approach is often easier in an emergency when a retroperitoneal haematoma has created a dissection plane.

Access to the *right renal artery*, as it crosses posterior to the inferior vena cava, and to the infrahepatic anterior aspect of the IVC is achieved by first mobilising the hepatic flexure of the colon, followed by 'Kocherisation' of the duodenum so that the head of pancreas can be lifted forwards. If access is needed to the posterior aspect of the whole vena cava, a right-sided medial visceral rotation is required, utilising the plane behind the right kidney and the liver, which must also be mobilised forwards. These mobilisation manoeuvres to gain access to retroperitoneal vessels are more easily understood in relationship to the embryological folding of the bowel and the subsequent layers of retroperitoneal structures (see Chapter 14).

The iliac vessels

ANATOMY

The *common iliac arteries* are the terminal branches of the aorta. They run inferiorly and laterally to the pelvic brim, where each divides into an internal and external iliac artery. The ureters cross the common iliac arteries and care must be taken to avoid ureteric injury during dissection. The *internal iliac arteries* run backwards and downwards into the pelvis. They then divide into multiple named branches, which supply the pelvic organs, in addition to the superior and inferior gluteal arteries, which supply the gluteal muscles where they form clinically important anastomotic collaterals with branches of the profunda femoris artery. The internal iliac artery can be ligated on one side without any adverse consequences. However, in the elective situation a patient should be warned of the risk of gluteal muscle claudication. The *external iliac arteries* continue downwards and laterally on the psoas muscle, passing behind the inguinal ligament to become the common femoral arteries. The *external iliac veins* lie on the medial sides of the arteries. The distal IVC and the confluence of the common iliac veins lie deep to the right common iliac artery (Figure 6.21). This anatomical arrangement is helpful in reconstructive aortoiliac surgery, but access to the common iliac veins in trauma can be very difficult. (It may be necessary to divide the artery for access and re-anastomose it afterwards.)

EXPOSURE

Exposure of the *iliac vessels* is seldom required in isolation, and additional exposure of either the aorta or the femoral artery often dictates the surgical approach. An *abdominal transperitoneal approach* is thus suitable for emergency surgery for iliac vessel trauma or aneurysmal rupture. The distal aorta and right iliac vessels are exposed by division of the overlying peritoneum. The left iliac arteries are exposed by division of the peritoneum lateral to the pelvic mesocolon. The ureters must be identified and safeguarded. Some damage is almost inevitable to the autonomic plexi overlying the vessels, but with care this can be minimised. In arterial trauma to the common femoral artery, a localised approach to the external iliac artery may be required for proximal vascular control. This situation after a cannulation injury was discussed above. An oblique muscle-cutting iliac fossa incision is made parallel to the inguinal ligament, but several centimetres above it, to avoid the inguinal canal and spermatic cord. The peritoneum is not entered but swept upwards and medially to expose the external iliac vessels lying on the pelvic brim on the medial edge of the psoas muscle (Figure 6.22). This *extraperitoneal approach* is also used in some elective reconstructive procedures (see Chapter 7). Clamps on iliac arteries should be placed from the front with one blade either side. Attempts to encircle the artery increase the danger of iliac vein damage.

The femoral arteries

The superficial position of the femoral arteries renders them vulnerable to trauma, including that self-inflicted by intravenous drug users. Iatrogenic injury is also common as it is a favoured entry site for endovascular investigations and therapeutic interventions. Elective access is also commonly required for reconstructive surgery.

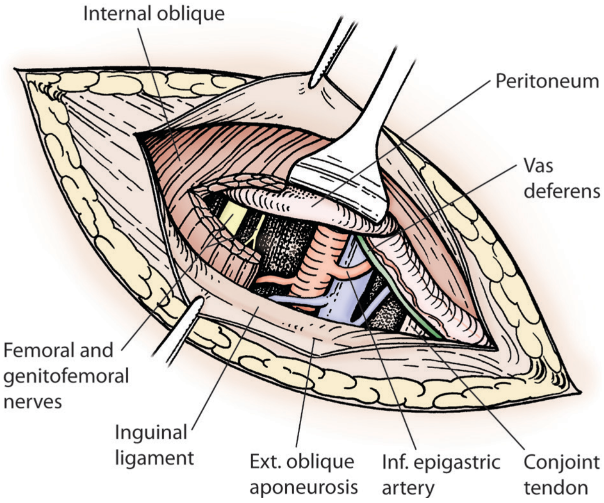

Figure 6.22 *Extraperitoneal exposure of the right external iliac vessels at the groin. Further retraction of the peritoneum would expose the termination of the common iliac artery and the ureter.*

ANATOMY

The *common femoral artery* commences as a direct continuation of the external iliac artery emerging from under the inguinal ligament at the mid-inguinal point. It runs obliquely downwards through the femoral triangle, with its bifurcation usually 3–4 cm below the inguinal ligament. The *superficial femoral artery* is the in-line continuation of the common femoral artery. It runs within the subsartorial canal, becoming the popliteal artery distally as it passes through the adductor hiatus. The *profunda femoris artery* (or *deep femoral artery*) is the other major branch arising from the posterolateral side of the femoral artery; it runs deep to the superficial femoral artery to disappear between the adductor muscles. At the inguinal ligament the femoral nerve lies lateral to the artery and the femoral vein is medial. Distally, the femoral veins lies posterior to the arteries.

EXPOSURE

Limited access is obtained via a transverse groin incision, but for more extended access a skin incision along the line of the artery is more suitable. The LSV will be encountered in the subcutaneous fat and should be preserved in case it might be required for reconstruction. The deep fascia is incised and the sartorius muscle mobilised. Sartorius is then retracted laterally to expose the common femoral artery and the origin of the profunda femoris. To expose the distal superficial femoral vessels, sartorius is retracted medially and the underlying bridge of fibrous tissue, which roofs over the subsartorial canal, is divided.

The popliteal artery

Emergency access to the popliteal artery is occasionally necessary in trauma. More frequently, it is required in reconstructive surgery for degenerative vascular disease.

ANATOMY

The popliteal artery begins as a continuation of the superficial femoral artery at the the adductor hiatus. It runs down through the popliteal fossa to end at the lower border of popliteus by dividing into the *anterior tibial* artery and the tibioperoneal trunk. The latter divides into *posterior tibial* and *peroneal* branches. The popliteal vein (which is often a pair of veins) is medial to the artery in its lower part but crosses it posteriorly to lie posterolateral to it in its upper part. The tibial nerve crosses the vessels posteriorly from the lateral to medial sides as it travels down the popliteal fossa.

EXPOSURE

An approach through a transverse popliteal incision, which can be extended into a lazy-S incison, is suitable for some procedures and is described in Chapter 7. However, the medial approach affords superior access in most

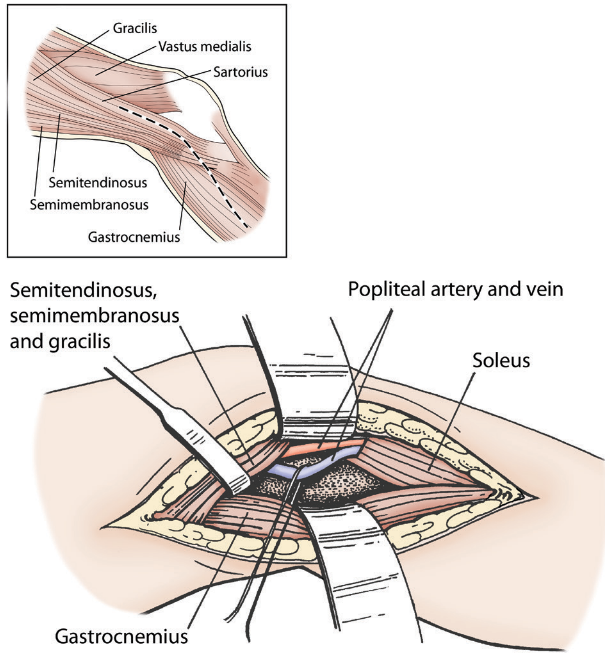

Figure 6.23 *Medial approach to the lower left popliteal artery. Only the lower half of the illustrated skin incision has been used, and the tendinous insertions into the proximal tibia are preserved and retracted anteriorly.*

circumstances. The separate above-knee and below-knee medial exposures are described in Chapter 7. In a traumatic emergency if more extensive access is needed, these two incisions can be joined (Figure 6.23). The tendons of sartorius, gracilis and semitendinosus, which all cross the operative field, can be divided and repaired at the end of the operation.

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7

OPERATIVE MANAGEMENT OF VASCULAR DISEASE

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VASCULAR PATHOLOGY

Arterial disease

While the spectrum of arterial disease includes tumour, infection and inflammation, the commonest pathological processes encountered by a vascular surgeon are aneurysmal disease, atherosclerotic occlusive arterial disease and embolic events.

ANEURYSMS

Aneurysms can be divided into true aneurysms, in which every layer is dilated but in continuity, and false aneurysms, in which there is a breach in the layers and rupture is prevented by thrombus, a single intact layer and the surrounding tissues. False aneurysms may result from trauma or infection; in the UK most are iatrogenic. The aorta, iliac, common femoral, popliteal and common carotid arteries are the most common extracranial arteries to be affected by true aneurysms. Other vessels may become aneurysmal, but this is less common. Frequently, discovery of an aneurysm is incidental to clinical examination or, more commonly, to an investigation for another reason. Others are detected through a targeted screening initiative. Those that are symptomatic may present as a mass, a pulsation or a feeling of pressure from the expanding aneurysm. Unfortunately, a significant number of aneurysms come to light as a result of a complication: commonly rupture, thrombosis or distal embolism and, more rarely, fistula formation or infection.

OCCLUSIVE DISEASE

Occlusive disease may present with moderate symptoms of insidious onset at one end of the spectrum, ranging to a dramatic symptomatic deterioration producing acute or critical ischaemia at the other end. Typically, occlusive disease has a relapsing–remitting course and only 5 per cent of the patients who present with claudication will ultimately lose the limb. The initial symptoms of claudication diminish as collaterals develop and then return as further segments of artery narrow or occlude. Many patients do not notice any symptoms until more than one segment is affected or long occlusions have developed, such is the compensatory capacity of a well-developed collateral bed. By far the commonest occlusive disease in the developed world is atherosclerosis. The majority of interventions are for lower limb arterial occlusions, but a vascular surgeon will also be required to treat occlusive arterial disease of the upper limb, the extracranial carotid circulation, the kidneys and the gut. The patients will almost invariably have widespread atherosclerotic changes that also affect the coronary circulation. An assumed coronary component must always be considered when assessing both individual and population risk and this is also part of the indication for the routine pharmacological secondary prevention with antiplatelet and statin therapy.

EMBOLIC DISEASE

An embolus presents as a sudden arterial event, the effect depending on the size and site of the embolus and the presence of an adequate collateral circulation. These collaterals may be normal anatomical pathways serving the same tissue bed (e.g. the radial and ulnar vessels) or anastomotic channels that have enlarged secondary to co-existent chronic occlusive disease. Large emboli can arise from the left atrium in atrial fibrillation or from the left ventricle in association with a ventricular aneurysm or a myocardial infarction. Emboli can also arise from the thrombus within an aneurysm in a more proximal part of the arterial tree. Atheromatous emboli from an unstable atheromatous plaque are usually smaller and often multiple, but their highly thrombogenic nature results in damage greater than expected for their size.

VASCULAR TRAUMA

Vascular trauma includes iatrogenic vascular injury and also the injuries sustained in a range of situations including military conflict and civilian violence. The relative importance of the various aetiologies will depend on the environment within which a surgeon practises, but puncture, crush, thrombosis *in situ* and dissection may all occur related to both penetrating and non-penetrating trauma. Vascular trauma is discussed in Chapter 6.

Venous disease

Varicose veins are incompetent, elongated, tortuous and dilated superficial veins (a varix is a localised aneurysmal dilatation of a vein). The condition is caused by valvular dysfunction, resulting in venous reflux with a subsequent increase in ambulatory pressure in the venous system. Varicose vein surgery is widely performed for ill-defined and quite varied symptoms and signs. Surgery is associated with high recurrence rates, modest patient satisfaction and frequent litigation.[1] However, patient demand for treatment of varicose veins is high and careful selection is imperative. Patients present with a spectrum of symptoms ranging from purely cosmetic concerns through to the skin changes of chronic venous insufficiency and ulceration. (The latter group have the most to gain from surgery on the superficial venous system.)

Deep venous thrombosis is common and the consequences are wide and varied. The natural history of an adequately treated deep venous thrombosis is generally complete thrombus resolution with minimal long-term symptoms. However, other complications such as pulmonary emboli are life-threatening emergencies and chronic venous ulcer disease is a highly morbid condition. The rare venous claudication from a chronically obstructed system can be incapacitating. Venous gangrene, resulting from massive occluding proximal thrombosis, is also rare. Incipient venous gangrene can be managed by aggressive leg elevation with the salvage options of thrombolysis or surgical thrombectomy.

SUPERFICIAL VEIN DISEASE

The majority (80 per cent) of varicose veins originate from the long saphenous vein (LSV). The remaining 20 per cent of varicose veins originate from the short saphenous vein (SSV). The proportion of limbs demonstrating incompetent calf perforating veins and deep venous or SSV reflux increases as the clinical status deteriorates.[2] Over one-third of patients with a leg ulcer will have SSV disease. Careful preoperative assessment is therefore essential. Some authors advocate imaging of all patients before varicose vein surgery. However, a pragmatic, resource-conscious approach is to perform a clinical and hand-held Doppler assessment on all patients with varicose veins, only referring those with recurrent varicose veins, skin complications of chronic venous insufficiency, varices of ambiguous distribution or audible venous reflux in the popliteal fossa for further imaging, such as a duplex scan.

Duplex scanning is non-invasive and provides both anatomical and physiological information on venous pathology, but it is operator dependent and may be time-consuming.

ANATOMY

The *great saphenous vein* (or *long saphenous vein*) commences as a confluence of vessels on the medial aspect of the foot and lies on the medial aspect of the limb in the subcutaneous fat until its termination at the saphenofemoral junction. It passes in front of the medial malleolus at the ankle, but behind the femoral condyle at the knee. Superficial tributaries and connections with the short saphenous system are variable. However, there are almost always several tributaries to the proximal few centimetres of the vein. There are also connections with the deep venous system via *perforators* (veins that perforate the deep fascia). In the thigh the perforators connect the LSV itself with the deep veins, but in the calf the perforators mainly connect the deep veins with the posterior arcuate tributary of the LSV (Figure 7.1).

The *small saphenous vein (or short saphenous vein)* is formed on the lateral side of the foot. It ascends behind the lateral malleolus and lies on the lateral and then the posterior aspect of the leg until its termination at the saphenopopliteal junction. The vein pierces the dense deep fascia of the popliteal fossa at a variable point from the upper mid-calf to just above the skin crease behind the knee. The saphenopopliteal junction is also variable in position, as is the length of vein lying beneath the fascia. This anatomical variation is in itself a strong indication for routine duplex scanning prior to short saphenous surgery.

Saphenofemoral junction ligation, stripping the long saphenous vein and phlebectomies

The patient is positioned supine with the hip very slightly flexed, abducted and externally rotated. General anaesthesia is normally preferred but if only a groin dissection is planned, local anaesthesia is satisfactory. The incision is commenced 1 cm below and 2 cm lateral to the pubic tubercle. If the groin crease is at this level, it is convenient to use this as it gives a superior cosmetic result. However, in obese patients the skin crease may be misleadingly lower and it is often affected by intertrigo, increasing the infection risk. The vein is usually palpable with the patient standing and can be marked

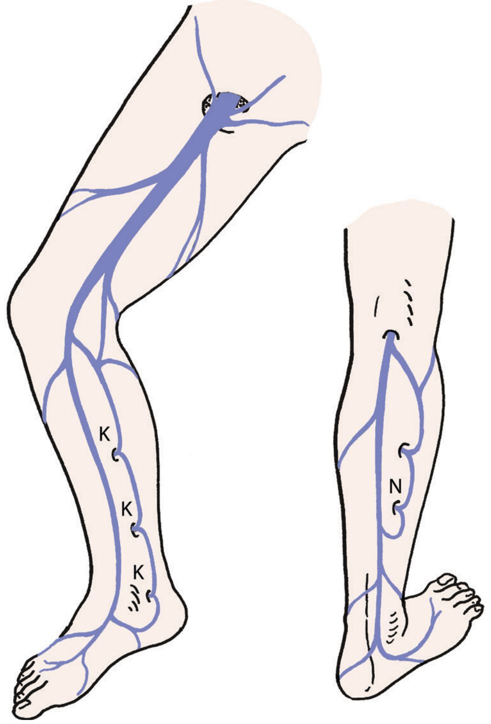

Figure 7.1 *The anatomy of superficial veins is very variable except for the main long and short saphenous trunks. The thigh perforators communicate directly with the long saphenous vein. Below the knee the perforators marked N and K communicate only with tributaries of the main trunks.*

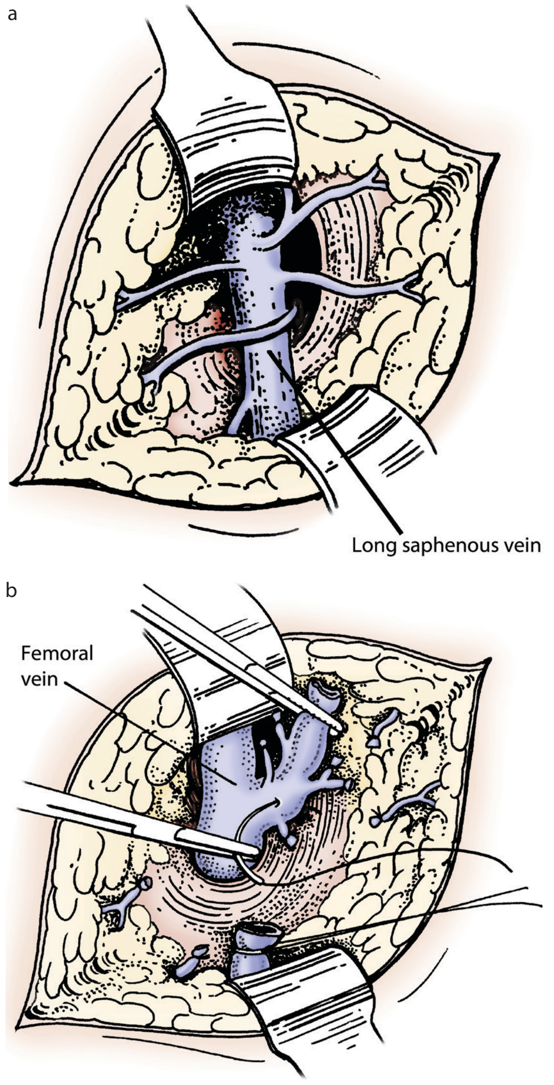

Figure 7.2 *Saphenofemoral ligation. (a) The terminal few centimetres of the long saphenous vein (LSV) and its tributaries are exposed. (b) The tributaries are ligated and divided. The proximal end of the LSV is lifted forwards to display the saphenofemoral junction and any remaining tributaries. Finally, the LSV is transfixed flush with the femoral vein.*

preoperatively. Alternatively, pulsation of the femoral artery lying immediately lateral to the vein is a useful landmark. The incision is deepened through the subcutaneous fat and then through a clear layer of superficial fascia (Scarpa's fascia). The deep venous system lies in the fat, deep to this layer. A correctly placed incision will expose the saphenofemoral junction, which should be cleared proximally and distally until the anatomy is revealed and the tributaries are defined (Figure 7.2).

The presumed LSV must not be divided until the anatomy has been unequivocally confirmed. The common femoral vein (CFV) must be clearly identified, continuing both proximally and distally in a deeper plane to the presumed saphenofemoral junction. The CFV is usually a different colour to the LSV. The external pudendal artery usually, but not invariably, crosses transversely between the two veins and may be ligated if necessary. The medial and lateral sides of the common femoral vein should be exposed, both to confirm the anatomy and to ensure that the medial tributaries, which may cause recurrences, and, according to some authorities, the vulval varices, are divided (or simply ligated if safer). The multiple tributaries to the saphenofemoral junction and the proximal LSV are then ligated and divided. Dividing the tributaries out at their first confluence may make recurrence from the formation of collateral channels less likely than if the ligated tributaries are lying in close proximity to the saphenous stump, although this is unproven. The LSV is then divided between artery forceps close to the saphenofemoral junction, so that the stump can be suture ligated in such a way that there is no deformity of the common femoral vein (Figure 7.2b). Narrowing this vessel with a stitch that is too deep, or leaving an overlong stump of LSV, may increase the risk of deep venous thrombosis.

The LSV is then stripped down to the level of the distal thigh. Stripping below this level increases the risk of damage to the great saphenous nerve. Leaving the LSV *in situ* in the thigh probably increases the rate of recurrence of varicose veins. The stripper, which is marketed in many forms, is passed down the LSV and retrieved through a short incision in the distal thigh (Figure 7.3). The stripper should remain palpable throughout its course, confirming that it has remained in the superficial veins and not traversed a perforator into the deep system. There is often a large medial upper thigh tributary, which can be ligated prior to stripping, reducing the chance of a groin haematoma. As the stripper is advanced down the vein there may be some resistance if the first valve is partially intact; this can normally be overcome with gentle pressure. At the distal incision the vein may tear as the stripper is retrieved. If the vein is intact, a small venotomy is made and the tip of the stripper delivered. The LSV is divided, tying the proximal end over the stripper and the distal end is ligated and allowed to fall into the wound. In the groin the upper end of the now isolated LSV is tied firmly around the stripper with a simple tie, without using one of the supplied stripper 'heads'. This tie should not be cut, leaving the ends long and thereby allowing the vein to be retrieved if the stripper slips under the tie. The stripper is then pulled down, inverting the vein, which will also avulse the tributaries and perforators. Bleeding can be reduced by tilting the table head down a few minutes prior to stripping if the entire operation has not been performed in this position. Stripping techniques that invaginate the vein are gaining popularity as they cause less trauma to adjacent tissue, although some surgeons still utilise the head supplied with the stripper.

Residual varices are then avulsed through a series of small incisions. (These dilated veins should have been marked preoperatively with the patient standing.) If there are a large number of phlebectomies to be performed, delivery of stripper and vein should be postponed until this has been completed to minimise bleeding and subsequent bruising. The limb can be bandaged or have a compression stocking applied as soon as the wounds are closed.

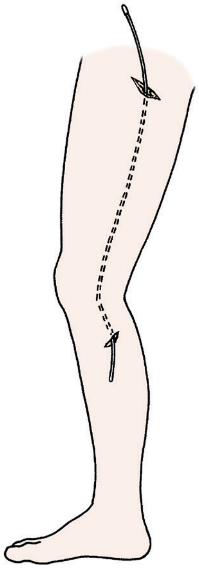

Figure 7.3 *The subcutaneous route of the stripper in the long saphenous vein is shown with a dotted line.*

Significant venous bleeding may occur during a varicose vein operation, caused by a tear to a major tributary or partial avulsion of a tributary from the common femoral vein. An anxious surgeon must avoid the temptation to apply artery forceps blindly, thereby damaging the femoral vein or even the artery. The appropriate first steps are firm pressure with a gauze swab and reduction of venous pressure by lowering the head of the table. It is important before assessing the damage to inform the rest of the theatre team of the situation, so that the availablility of suction equipment is ensured and the anaesthetist can secure appropriate venous access. If the damage is reassessed after a 5-minute delay, often the bleeding will have ceased and accurate application of artery forceps to a vessel, or the repair of a femoral vein tear, will be easier. If there is still a major problem, blood should be cross-matched, assistance summoned and the incision enlarged before attempting definitive repair.

GROIN SURGERY FOR RECURRENT VARICOSE VEINS

Surgery for recurrent varicose veins is associated with significantly greater morbidity and poorer patient satisfaction than varicose vein surgery in an unoperated groin. Recurrence associated with reflux from the groin results either from incomplete saphenofemoral disconnection at the original operation or from neovascularisation resulting in new connections between the common femoral vein and an LSV that was not stripped but left *in situ* in the thigh.[3] Recurrence can also occur through a mid-thigh perforator with reflux into a persistent LSV. Preoperative imaging by duplex scanning is essential.

If significant reflux is demonstrated at the groin, then re-exploration of the groin may be considered. The skin incision is usually placed transversely, although some surgeons advocate a vertical incision just medial to the pulsation of the artery. The key is to define an unscarred tissue plane at the level of the common femoral vein above and below the connection to the superficial system. Dissecting down to the common femoral artery establishes the depth; the common femoral vein is immediately medial to this. Neovascularisation should be avoided as these vessels are thin walled and difficult to dissect. Having defined the common femoral vein above and below the saphenofemoral junction, all of the anterior tissue can be isolated. The scarred tissue, with thin-walled veins, at the junction itself is left until last and is then finally ligated and divided. In recurrent groin surgery for varicose veins, the LSV should be stripped if this was not done at the original operation.

If the groin component is trivial, especially if the LSV is fed by a mid-thigh perforator, stripping from the level of the knee up as far as possible, without re-exploring the groin, can be considered to minimise morbidity. The stripper can be retrieved below the previous skin incision and any proximal stump ligated.

Short saphenous vein ligation

The position of the saphenopopliteal junction is highly variable. The upper portion of the SSV is not easily palpable after it has pierced the fascia. It is important to mark the vein and its termination preoperatively by venous duplex scanning. The patient is best positioned prone, which has implications for the anaesthetic and nursing teams.

A transverse skin incision is made over the vein about 2 cm below its termination. The vein may be seen through the deep fascia. The deep fascia is then divided. The vein is dissected until an artery forceps can be passed deep to it, with care taken to avoid damaging the accompanying, and often adherent, sural nerve. The vein is divided between artery forceps and the distal end ligated. The proximal end is then followed deep into the popliteal fat. The finding of multiple tributaries from muscle heralds the approach of the saphenopopliteal junction. These tributaries are easy to tear and tying them off is time-consuming and often difficult. Ligation of the SSV just short of the junction is satisfactory in most cases. In addition, the saphenopopliteal junction is not always a distinct T-junction, as found in the groin, and the vein may terminate amongst a plexus of thin-walled deep veins. Overzealous dissection may damage these, with resultant haemorrhage, which is difficult to control, putting at risk the artery and tibial nerve. However, there is frequently a superior tributary to the last centimetre of the SSV. This tributary is the termination of a superficial vein that may also communicate with the long saphenous system. It is important to ligate and divide this potential source of recurrence.

There is great anatomical variation. The SSV may enter the popliteal vein well above the popliteal skin crease, and on occasion an incompetent SSV may have no communication with the popliteal vein. The superior branch may be so large that it appears as a continuation of the main vein with only a short side communication between superficial and deep veins at the level of the popliteal skin crease. This variant must be considered as it can be damaged by rough passage of an instrument deep to the SSV, especially if the preoperative marking has been misleading.

Perforating veins

A thigh strip will avulse significant thigh perforators. Perforating veins in the calf do not join the LSV directly, and stripping of the main vein to the ankle does not treat them (see Figure 7.1). Direct surgery for incompetent calf perforators is best performed by a subfascial endoscopic approach. There are usually severe skin changes in the area and incisions directly over the vessels are unlikely to heal satisfactorily. An incision through healthy more proximal skin and deep fascia allows access to the plane between the muscle and deep fascia. The perforating veins crossing this plane can be ligated and divided. However, many incompetent perforators return to normal function with superficial surgery alone.[4]

Minimally-invasive venous surgery

The surgical management of varicose veins has evolved in recent years and many would now advocate minimally-invasive endovenous intervention.[5] One major advantage of these techniques is avoidance of general anaesthesia, the procedures being performed using tumescent local anaesthetic infiltrated around the LSV under ultrasound guidance. All three endovenous techniques (endovenous laser therapy, radiofrequency ablation and foam sclerotherapy) cause injury to the vessels and rely on subsequent thrombosis and long-term occlusion following a short period of compression. The vein is cannulated at the level of the knee under venous duplex guidance using the Seldinger technique. The probe or catheter is then passed up to the saphenofemoral junction and then gradually withdrawn, applying heat, light or chemicals to damage the vein. The tumescence is vital as a heat sink to prevent thermal damage to the skin. Foam sclerotherapy may be used to manage minor calf and thigh varices.

Minimally-invasive venous surgery minimises post-procedural discomfort and may allow a more rapid return to function when compared with open surgical intervention. The long-term results would seem equivalent to those of open surgery.

Complications of superficial venous surgery

Litigation is common after unsatisfactory outcome following varicose vein surgery, so prior to embarking on surgical intervention it is important that patient expectations are managed and potential complications are explained. These include the significant risk of wound infection (higher for repeat groin surgery), peripheral nerve injury resulting most commonly in sensory loss in the distribution of either the great saphenous nerve or sural nerve, deep venous thrombosis and recurrence.

CHRONIC VENOUS INSUFFICIENCY

The management of patients with chronic venous insufficiency and venous hypertension is a major topic and cannot be covered completely in a general operative text. The majority of patients with chronic venous insufficiency will have identifiable reflux within the deep or superficial venous sytems, or both. In some patients superficial venous reflux is the sole cause of their venous hypertension and in others it is a significant factor. Some of these patients may benefit from varicose vein surgery. In 20 per cent of patients with chronic venous insufficiency the pathology is confined to the deep veins, and in a further 40 per cent deep venous pathology is a contributory factor. Symptomatic patients may present with a swollen leg and skin changes, including venous ulceration. Duplex scanning will confirm the distribution of the venous incompetence in the deep and superficial systems and will also demonstrate any chronic occlusive changes of the deep veins. Management of the ulcer itself is non-operative, relying on measures to improve venous return through elevation of the limb when at rest and techniques for leg compression.

If superficial venous reflux is a significant contributory factor, varicose vein surgery should be considered. The time to ulcer healing may not be reduced, but a reduction in ulcer recurrence is reported.[6] Very occasionally, reconstructive surgery to deep veins may be appropriate.

Venous bypasses and operations to restore competence to the valves of deep veins have not been universally adopted as, except in specialist centres, the results are disappointing. The intermittently sluggish flow in veins and the high incidence of thrombophilia in these patients at least partly explain these results. Venous angioplasty and stenting offers another option for patients with chronic iliac system occlusions. Patency rates may be enhanced by creation of an arteriovenous fistula (see below).

Saphenous crossover graft (Palma procedure)

This bypass procedure can restore venous drainage when there is a unilateral iliac vein occlusion. Although only a minority of patients with chronic venous insufficiency have an isolated occlusion at this level, they may have particularly severe symptoms including incapacitating venous claudication. The LSV on the contralateral side is used as the bypass. The LSV is mobilised from groin to knee and divided distally, but the saphenofemoral junction is left intact. In addition, the tributaries around the junction are preserved to maintain the normal alignment of the vein and prevent kinking. The femoral vein on the opposite limb is exposed in readiness to receive the vein graft. A suprapubic subcutaneous tunnel is created through which the vein graft is passed. An end-to-side anastomosis is then performed (Figure 7.4).

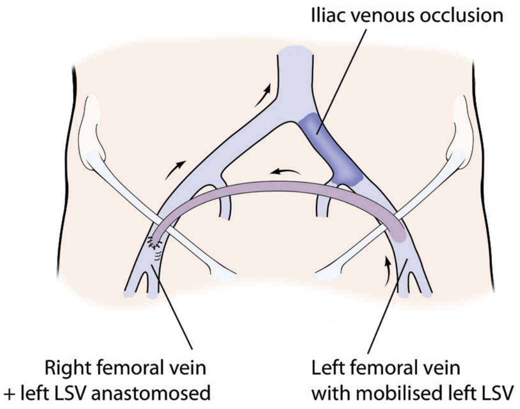

Figure 7.4 *A Palma crossover vein graft for an occluded left common iliac vein. The left long saphenous vein (LSV) has been brought across for an end-to-side anastomosis onto the right femoral vein.*

Temporary arteriovenous fistula

This addition to the procedure described above is favoured by some surgeons to increase flow through the graft in the early postoperative period, when the danger of thrombosis and graft occlusion is highest. Once this period is over, the arteriovenous fistula is closed by radiological intervention. A separate vein or prosthetic graft, or the end of the LSV (as illustrated in Figure 7.5), can be used to create the arteriovenous fistula.

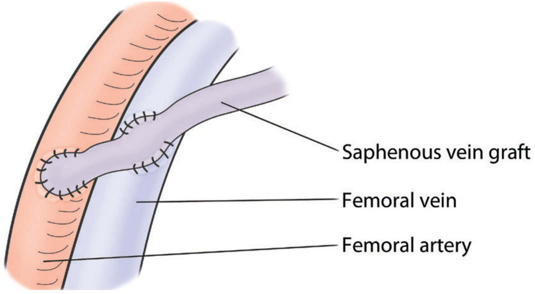

Figure 7.5 *An arteriovenous fistula has been created by anastomosing the vein graft onto both the common femoral vein and artery.*

INFRARENAL AORTIC ANEURYSMS

Successful surgical repair of abdominal aortic aneurysms (AAAs) was first reported during the 1950s.[7] Open repair is now commonplace, with endovascular aneurysm repair an alternative option.[8] The situation is not static, with continued industry-driven development extending the endovascular possibilities. Aneurysmal dilatation may be localised to the aorta or extend into the iliac arteries. Fortunately, aneurysmal dilatation involving the suprarenal or thoracic aorta is less common, as the surgery for these thoracoabdominal aneurysms is technically challenging, with significantly higher rates of adverse events. AAAs are predominantly secondary to atherosclerotic degeneration, a process that may also result in occlusive disease. A mixed pattern of occlusive and aneurysmal disease may therefore be encountered.

SELECTION

Elective repair of infrarenal AAAs is a prophylactic procedure to prevent death by rupture. Open repair is associated with a mortality rate of around 5–10 per cent. Endovascular aneurysm repair has a 30-day mortality of less than 2 per cent. After rupture, the mortality rate in the minority who survive the initial bleed, subsequently reach hospital and are selected for repair may be as high as 50 per cent. It therefore seems appropriate to identify those at risk of rupture and to offer surgery before rupture occurs. However, the true natural history of aneurysms remains undefined. Evidence from the UK Small Aneurysm Trial suggested that the rupture rate of AAAs less than 6 cm in anteroposterior diameter on ultrasound scan had previously been overestimated and that surveillance of these small aneurysms was appropriate.[9] It is now generally accepted that intervention should be considered when the anteroposterior diameter exceeds 5.5 cm.

Patient selection is a contentious area and preoperative investigations are determined by local protocols that are often dependent on availability and cost. Patients considered for elective AAA repair require assessment over and above simple exercise tolerance estimation and electrocardiography. Echocardiography (with or without pharmacological stress), an assessment of renal and pulmonary function (spirometry) and cardiopulmonary exercise testing are advocated, but predictive preoperative investigation is far from a precise science and much remains to be refined.

Although simple ultrasound is useful to diagnose and monitor AAA growth, more detailed anatomical information is required preoperatively to exclude suprarenal aneurysmal extension, verify the position and number of renal arteries, and to identify iliac artery aneurysmal or occlusive disease. CT angiography is currently the standard investigation.

The operation

The patient is usually operated on in a supine position, and skin preparation and draping must allow access to the femoral vessels. Prophylactic antibiotics are administered according to local protocol. The abdomen may be opened using a midline or a transverse incision. The transverse colon is lifted up and packed superiorly and the small bowel is displaced to the right into a bowel bag outside the abdomen or packed within the abdomen. An incision is made just lateral to the fourth part of the duodenum, leaving sufficient peritoneum as a cuff to allow restoration of peritoneal coverage afterwards. The third part of the duodenum is mobilised from the front of the aorta, and the pre-aortic tissue is divided to approach the neck of the aneurysm on the bare aortic wall. The inferior mesenteric vein is routinely encountered, ascending on the left of the aorta, and is either divided between ties or displaced upwards.

The dissection is routinely continued up to the level of the left renal vein, not only to create sufficient room to clamp above the aneurysmal tissue, but also to confirm the anatomy with a landmark visible on CT (Figure 7.6a). Occasionally, it is necessary to divide the left renal vein. Some authorities advocate routine reconstruction of the left renal vein at the end of the procedure to avoid deterioration in renal function; division is certainly associated with a greater mortality. Aortic aneurysms rotate and lengthen as well as expand in diameter, and the sides of the aorta need to be exposed carefully to avoid damage to lumbar arteries, as well as to an accessory renal artery. Tearing the left iliolumbar or gonadal veins is a significant hazard and sometimes it is easier to divide these vessels between clips, rather than attempt to preserve them.

Exposure of normal aorta just proximal to the aneurysm – often referred to as the neck – is not complete until a clamp slides easily down the sides and rests on the spine.

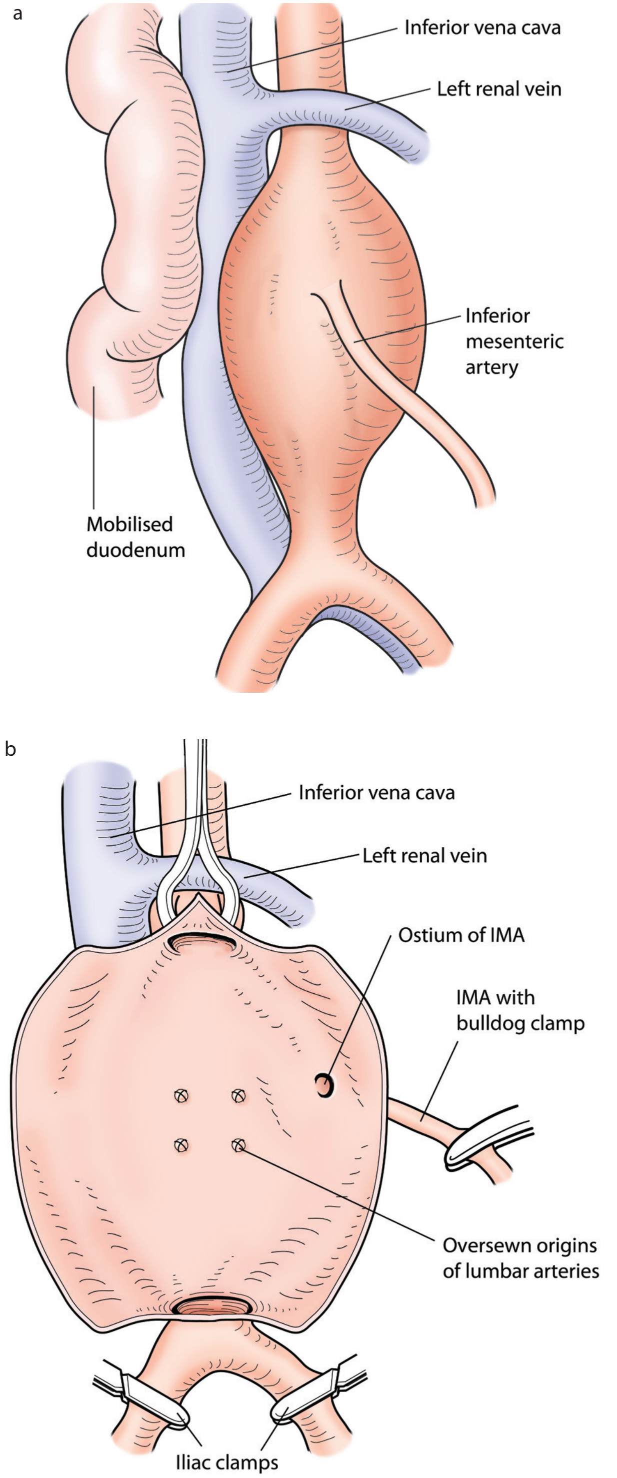

Figure 7.6 *Abdominal aortic aneurysm repair. (a) Exposure of the neck of the aneurysm. (b) The opened aneurysmal sac. Note the open ostium of the inferior mesenteric artery (IMA), which will be excluded by the graft.*

The next objective is exposure and control of the iliac arteries, with awareness of the course of the ureter. It is not necessary, or desirable, to pass tapes or slings round these vessels. This is potentially hazardous, risking damage to the often adherent iliac veins. The right common iliac artery is covered only by a single layer of peritoneum and retroperitoneal fat. The first part of the left common iliac artery is immediately deep to the peritoneum, and this may allow adequate access for clamping depending on the distal extent of the aneurysm or any occlusive disease. However, it may be necessary to clamp more distally, requiring partial mobilisation of the sigmoid colon and clamp placement just above the inguinal ligament. Frequently, the aneurysmal process on one or the other side extends up to the iliac bifurcation. This presents two problems. Firstly, the internal iliac artery must be exposed, to allow separate occlusion. Secondly, the perfusion of the pelvic organs requires some thought as, after sacrificing the inferior mesenteric artery (IMA), the rectum is dependent on retrograde perfusion from the internal iliac arteries. Overt rectal or left colon ischaemia requiring surgical intervention occurs infrequently (in 1–2 per cent of cases) following AAA repair, but subclinical mucosal ischaemia may be more common. It is generally considered sufficient to leave a minimum of one out of the three arteries (the IMA and the two internal iliac arteries) in circulation and in AAA surgery the inferior mesenteric inflow from the aorta is lost unless the vessel is reimplanted. Sometimes, the distal limb of a bifurcated graft can be fashioned to include the origin of the internal iliac artery, but occasionally a vessel must be formally reimplanted or a jump graft performed. Decisions regarding bowel perfusion are based on inspection at the end of the procedure.

After adequate exposure of the aneurysm, 5,000 IU of unfractionated heparin is administered intravenously and the vessels clamped. Clamping distally first may minimise the risk of embolisation and is certainly recommended if the patient presented with distal emboli.

The aorta is opened longitudinally at a convenient site, and care is taken to incise to the right of the IMA origin (Figure 7.6b). The arteriotomy is extended up and down the vessel to a distance 1–2 cm short of the neck proximally and 1–2 cm short of the bifurcation distally. The inside of the vessel is then inspected and the anatomy of the neck and bifurcation confirmed. The thrombus, which is almost invariably present, must be scooped out and the aneurysm sac wiped clean with a swab. Any sites of back bleeding from the lumbar, inferior mesenteric or median sacral vessels revealed by this must be controlled by a figure-of-eight suture, but for the IMA a bulldog clamp, applied plush with the edge of the sac, is more appropriate in case reimplantation of the artery is desirable. A self-retaining retractor can be placed within the sac itself. Often, the back wall of the aorta, particularly at the distal end, is very calcified and a controlled local endarterectomy may be needed to allow a stubborn vessel to be adequately sutured.

The longitudinal arteriotomy incision is then extended to the proximal limit of the aneurysm and converted into a T-shape by cutting at 90 degrees to the longitudinal line of the aorta around the true circumference of the vessel (Figure 7.7a). At this level, even normal aortic tissue may arch anteriorly and, particularly in the presence of a large aneurysm, care must be taken not to cut straight backwards as this can make the proximal anastomosis more difficult. The distal end of the arteriotomy is completed in a similar fashion after a decision has been reached as to whether a 'tube graft' or bifurcated 'Y-graft' is more appropriate. If the aorta is of normal calibre for a portion below the aneurysm, or if the common iliac arteries are truly normal and closely opposed, a tube graft may be used (Figure 7.7b). Otherwise, a bifurcated graft is needed (Figure 7.7c). The diameter of the graft to be used is then estimated, based on the use of sterile 'sizers' or simply by 'eyeballing' the neck and comparing this with the size drawn on the unopened graft box.

Proximally, an inlay anastomosis is performed (see Figure 6.13, p. 93). If bifurcated, the body of the graft must be trimmed to within 3 cm of the diverging limbs in order to avoid kinking. There is a variety of techniques used for the proximal anastomosis. Most frequently, the anastomosis is performed with a continuous 2/0 or 3/0 monofilament, non-absorbable, double-ended suture. This is commenced posteriorly with a mattress suture into the graft and continued in both directions around the posterior and lateral aspects of the anastomosis. After six or so sutures have been placed, they are tightened and the graft parachuted into position. The anterolateral aspects of the anastomosis are then completed on either side before tying the sutures together just off the midline anteriorly. An anterior knot immediately over the convexity of the aorta is more likely to come into direct contact with bowel, increasing the likelihood of infective or fistulous complications. Interrupted, evenly spaced mattress sutures may be a better alternative when the aortic wall is grossly thickened and friable, but unless the posterior aortic wall has been transected, the posterior sutures will have to be placed from within, with the knots lying within the lumen. Whatever the chosen technique, the posterior wall must be secured with deep bites, often into and including the anterior spinous ligament. When the proximal anastomosis has been completed, the graft is clamped 2–3 cm distal to the anastomosis and the proximal aortic clamp is released to test the anastomosis. Any bleeding points identified need to be dealt with as appropriate, after reclamping the aorta. Figure-of-eight sutures may be enough, but some bleeding may be due to tears in the aortic wall. Interrupted horizontal mattress sutures, supported by little patches of the graft material, are recommended to repair these and to prevent extension of rents in a friable aortic wall. An entire cuff of Dacron, cut from the graft, can be used over a vulnerable anastomosis to provide additional support.

The graft needs to be trimmed to its final length, allowing a modest degree of tension to prevent the prosthesis from bowing forwards or kinking. The distal anastomosis is performed in a similar fashion to the proximal. Before completing the suture line, the graft must be flushed by releasing the clamps and allowing the flow of blood to remove any thrombus that has formed. The iliac vessels also require to be opened to demonstrate back-bleeding. If there is no back-bleeding, 'pumping' the thigh by external compression may stimulate blood flow. Failing this it may be necessary to pass Fogarty catheters to remove clots.

When the distal circulation is restored, a fall in systemic blood pressure and perfusion is likely. This is due to a sudden reduction in systemic vascular resistance and the return of cold, deoxygenated blood laden with free radicals, activated white cells, carbon dioxide and lactic acid, all of which are cardiodepressant and also cause pulmonary vascular vasoconstriction. The anaesthetist must be warned before releasing the clamps, one leg at a time. The patient's vascular compartment should be adequately filled and fluids and pressor agents should be to hand to deal with a sudden fall in systemic blood pressure. The surgeon must pay attention to the effects on systemic blood pressure. If the pressure drops precipitously, it can be brought up again by partial or full occlusion of the graft. However, a 10–20 mmHg drop in blood pressure and a rise in end-tidal CO_2 is reassuring. This, together with the return of a palpable femoral pulse, indicates the restoration of blood flow to the lower limb.

Before closing the aortic sac and reconstituting the peritoneum over the graft, the following checks are necessary:

- Is the colon adequately perfused and is the IMA back-bleeding? If so, does the origin of the IMA require suture ligation? If the left colon appears ischaemic and the IMA is patent, implantaton of the IMA into the graft may be indicated.
- Have any lumbar arteries started back-bleeding now that the distal circulation has been restored?
- Are both femoral pulses present (if they were palpable preoperatively), and are the feet well perfused?

If all is well, the aneurysm sac is sutured over the graft (Figure 7.7d) and the peritoneum is also restored. The small bowel and omentum can be eased toward their normal positions and care must be taken to leave no part of the graft exposed to which adjacent gastrointestinal tract could adhere, with subsequent risk of infection or fistulation.

RETROPERITONEAL APPROACH

This is an alternative approach for an elective AAA repair. The patient is positioned supine with a tilt elevating the left side. A left oblique muscle-cutting incision is made through the abdominal wall muscles, and the peritoneum is retracted medially to give good access to the retroperitoneal abdominal aorta. This approach may be associated with a reduction in ileus and reduced haemodynamic and respiratory compromise, resulting in quicker postoperative recovery. In addition, intra-abdominal pathology, such as adhesions from previous surgery, can be avoided. Access is superior if visceral reconstruction is also necessary. The main disadvantage of a retroperitoneal approach is the poor access it affords to the right iliac vessels.

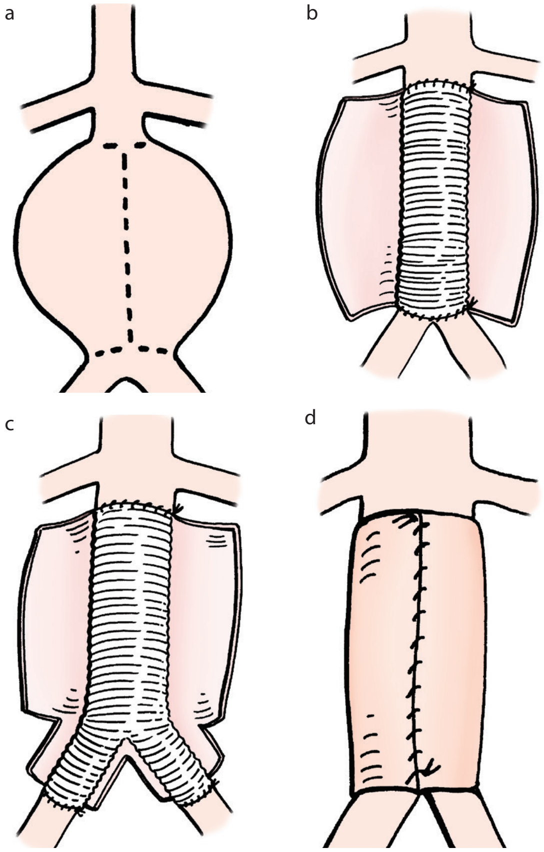

Figure 7.7 *Diagrammatic representation of an aortic graft. (a) The arteriotomy incisions. (b) An opened sac with an in-lay tube graft in position. (c) An opened sac with an in-lay Y-graft in position. (d) The sac has been closed over the graft.*

Inflammatory aneurysms

Around 5 per cent of AAAs are inflammatory. The main clinical feature is the pearly white appearance to the aortic wall. The inflammatory component involves the surrounding tissues and organs, particularly the duodenum. This condition is related to the more diffuse inflammatory process of retroperitoneal fibrosis. In the majority of cases the diagnosis is made at operation, although certain features support a preoperative diagnosis, for example, presentation with a systemic illness, including fever and malaise, and raised inflammatory markers. The appearance of a halo around the aneurysm or an associated hydronephrosis may have been detected on imaging. Some patients with inflammatory aneurysms present with symptoms relating to ureteric obstruction, and urological investigations lead to the diagnosis.

As the surrounding inflammation offers no protection from rupture, the indications for surgery are similar to those for other AAAs, but with increased operative difficulty. At operation the patient is more likely to require a suprarenal clamp and the surrounding structures, particularly the duodenum, are at greater risk of damage. It may be necessary to clamp the aorta without separating the duodenum from the aneurysm. The patch of aortic wall adherent to the duodenum can then be excised from the aorta after the aorta has been opened, leaving the adherent patch of aneurysm wall on the duodenum. Ureterolysis is advocated by some, but the risk of ureteric damage is high. It is usually unnecessary as the inflammation tends to settle following surgery and ureteric obstruction usually resolves. Ureteric obstruction at presentation can be managed by ureteric stents and the placement of stents preoperatively will help reduce the risk of iatrogenic injury.

Ruptured abdominal aortic aneurysm

PREOPERATIVE MANAGEMENT

The diagnosis may be straightforward. A history of collapse together with a clinical, or ultrasound, finding of an AAA is sufficient grounds upon which to proceed to emergency repair, especially if the patient is unstable. Occasionally, diagnostic difficulties occur either regarding the presence of an aneurysm or whether rupture has occurred. CT should not be performed in haemodynamically unstable patients but may be helpful, particularly if an alternative diagnosis is found. However, it cannot be completely relied upon to exclude rupture of an AAA.[10]

A preoperative chest X-ray is desirable, especially as it may indicate a thoracic component to the aneurysm. An ECG is usually performed, and difficult decisions may ensue if myocardial ischaemia or infarct is strongly suspected. This may be secondary to hypotension but the prognosis is significantly poorer.

The surgical principles for repair of the ruptured AAA differ only a little from the elective situation. However, mortality is much higher. In the UK most surgeons operate selectively on ruptured AAA. Experienced clinical judgement is essential, but these difficult decisions can now be supported by scoring systems.[11,12]

After the decision has been made to proceed, there is often considerable urgency. Although an arterial line is helpful, it should not delay induction of anaesthesia; both this and central venous cannulation can wait until surgery is underway. Urethral catheterisation and good peripheral venous access are, however, essential, as is communication with the blood transfusion service so that blood can be cross-matched and fresh-frozen plasma and platelets organised. There is often a dramatic fall in blood pressure on induction of anaesthesia, in part due to the loss of tamponade as abdominal muscle tone is eliminated following paralysis. Therefore, the patient should be prepared and draped prior to induction of anaesthesia so that there is no unnecessary delay before the haemorrhage can be controlled surgically.

THE OPERATION

The operative procedure is essentially the same as described above for the elective situation. A transverse incision may still be chosen over a midline: access is usually adequate. However, many consider a midline incision to be a quicker approach.

It is rare for a patient to survive to reach the operating theatre with free intraperitoneal rupture. When a free rupture is encountered at laparotomy, pressure applied directly to the neck of the aneurysm may control the bleeding. Alternatively, an aortic balloon catheter (or large Foley catheter) can be passed up the aorta, beyond the neck of the aneurysm (see Figure 6.3a, p. 87). This is a difficult manoeuvre in an emergency situation and may lead to significant blood loss. If control at the neck is still difficult, then the aorta can be temporarily clamped through the lesser sac. A window is opened in the lesser omentum and the aorta can be exposed and clamped by separating the fibres of the diaphragmatic crura from the aorta (see Figure 6.21, p. 103). Visceral ischaemia will occur and the effects of clamp release will be profound. Therefore, the clamp should be moved down to an infrarenal position as soon as this is possible.

Fortunately, the situation is usually a stable one, the haematoma is contained by the peritoneum and a careful dissection can be performed. The duodenum is most frequently displaced to the right by the haematoma and therefore already partially mobilised. Dissection can proceed with division of the peritoneum and exposure of the aneurysmal aortic wall. The aorta should be followed superiorly, dividing the inferior mesenteric vein as it is encountered. Bleeding, either active or from the haematoma, will inevitably obscure the view, and the assistant needs to be active with suction in one hand and a retractor in the other. Care must be taken to identify the neck of the aneurysm, and this often requires dissecting all the way up to the renal vein, as in the elective case. Careful clamp placement is essential. It is easy to damage the inferior vena cava (IVC), left renal vein or any other adjacent vein by hastily forcing a clamp into place. Usually, the aorta is clamped before exposing the iliac vessels. If the iliac arteries are also aneurysmal, they must be excluded by the repair. It is also possible that the rupture has occurred through the wall of an iliac artery.

If the situation is truly stable and the haematoma modest in size, some surgeons will administer heparin once the aorta is clamped; the patient is more likely to suffer a thrombotic complication than a haemorrhagic complication. Other surgeons flush heparinised saline down the iliac systems to reduce the possibility of iliac or femoral thrombosis while the repair is being performed.

Repair proceeds as for elective AAA surgery, but special care must be taken to ensure that the iliac arteries are back-bleeding before completing the distal anastomosis. If there is no back-flow of blood from the legs, it is prudent to sweep the distal vessels with a Fogarty catheter at this stage. As with the elective situation, perfusion of the feet must be checked before the patient is taken from the operating table.

Inevitably there are occasions when the situation is not salvageable:

- The patient may arrest or suffer a myocardial infarction with loss of cardiac output despite the use of inotropes.
- Irreversible coagulopathy may develop.
- The aneurysm may be inoperable (for example extension high above the renal arteries) or the aortic defect may be exposed by dissection and rapid and uncontrollable haemorrhage ensue.
- Whatever the circumstances, a decision to abandon the procedure may have to be made. This is best taken in conjunction with other colleagues present.

AORTOCAVAL FISTULA

Occasionally, an aortocaval fistula is encountered. This may have been suspected preoperatively if the patient presented with high-output cardiac failure and was noted to have mottling of the lower half of the body despite apparently adequate perfusion in the upper half. An abdominal bruit or thrill may have been detected. The proximal aortic clamp is applied and the aorta opened in the usual fashion. The fistula is then oversewn from inside the aortic sac with a heavy monofilament suture. Temporary control can be gained by local digital pressure on the IVC above and below the fistula. The above description of the clinical presentation is well known, but many fistulae are incidental findings, only diagnosed when dark blood from the cava appears as the thrombus is lifted out of the aneurysm.

Mixed aneurysmal and occlusive disease

Although most elective aneurysm surgery is performed entirely within the abdomen, the presence of iliac occlusive disease may necessitate exposure of the groin to find suitable outflow vessels. Increased operative complexity increases the morbidity but there is also increased mortality, perhaps to as much as 10 per cent. The presence of occlusive disease indicates a higher risk of latent coronary, cerebral and visceral atheromatous disease, and therefore an increased risk of perioperative myocardial and cerebral infarction and of renal failure.

Planning requires adequate arterial imaging, usually in the form of a CT angiogram. The aortic aneurysm replacement is combined with a bypass to the common, superficial or profunda femoral artery. As before, some thought must be given to the pelvic circulation at the end of the procedure. If there are no internal iliac vessels visible on imaging, and the IMA is patent, then this vessel may need reimplanting. If an internal iliac artery is patent and the external iliac artery is patent from the groin up, then retrograde perfusion can be expected to be sufficient (Figure 7.8). However, difficulties arise if the external iliac artery is occluded and both the internal iliac arteries (or the only remaining patent internal iliac artery) are perfused by patent common iliac arteries, which will be excluded by the bypass. In this situation, if the IMA is also chronically occluded, a jump graft may be needed to the internal iliac artery. However, if there is angiographic evidence of chronic occlusion of these vessels, or they exist on the angiogram as isolated segments, then special efforts to revascularise are not necessary, as collaterals will already have developed. Additionally, any revascularisation surgery is unlikely to be successful.

When surgery is undertaken for mixed aneurysmal and occlusive disease there are some modifications to the operation described above for simple aneurysmal disease. If a bypass to the femoral system is anticipated, it is usual to explore the groins before opening the abdomen. Once a suitable site for the distal anastomosis is confirmed, tunnels for the graft are formed. An index finger is gently inserted, nail down, in front of the common femoral artery and a space created into the pelvis. The surgeon must be aware of the deep circumflex iliac vein, which runs over the distal external iliac artery and is easily torn. Once this space has been fully opened to the limit of the finger, the tunnel is completed from above once the abdominal component has been completed. From inside, an index finger is gently advanced in front of the common iliac artery, pushing peritoneum and, more importantly, the ureter in front of the proposed tunnel. The two fingers will meet and a little, gentle, circular action of the fingertips may be required to break down the last

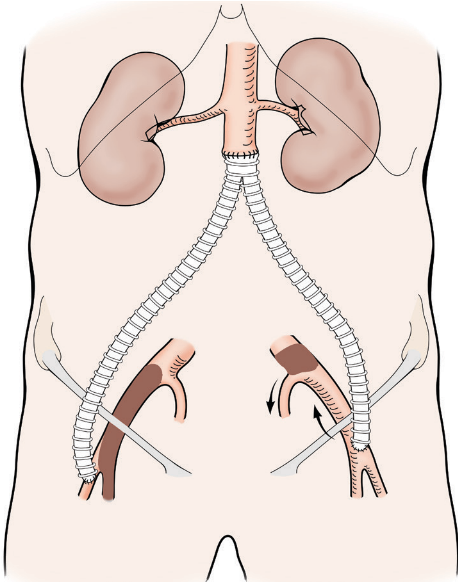

Figure 7.8 *An inlay aortobifemoral graft for mixed aneurysmal and occlusive disease. The origins of the inferior mesenteric artery and of the internal iliac arteries have been excluded by the graft. On the patient's right, the external iliac and common femoral arteries are occluded, the graft has been taken to the superficial femoral artery and no retrograde flow is possible. On the patient's left, the graft has been taken to a patent common femoral artery and pelvic perfusion can be maintained by retrograde flow up the left external iliac artery.*

intervening connective tissue. A long instrument is then passed up the tunnel and a tape pulled down to the groin wound. The tape is clipped and left *in situ* to ensure that the track can be found again when the time comes to pass the limbs of the graft down into the thigh. The tunnels are usually formed before administration of heparin and, therefore, before the proximal anastomosis has been performed.

Proximal and distal clamps are then applied and the aneurysm sac opened as described above. After completion of the proximal anastomosis, each limb of the graft is brought through its respective tunnel and anastomosed end-to-side onto the appropriate segment of femoral artery. A final consideration is closure of the proximal ends of the iliac segments. The common iliac arteries are usually clamped or occluded by balloons, but after the top end of the graft is secured, the common iliac arteries must be sutured closed. This requires a double row of non-absorbable, heavy, monofilament sutures, and haemostasis must be checked at the end of the procedure. Even in the case of chronic total occlusion of the iliac segment, there remains a chance of back-bleeding when the clamps are released at the completion of the distal anastomoses.

Endovascular aneurysm repair

The first endovascular aneurysm repair, by Parodi *et al.* in 1991, resulted in a revolution in the management of AAA.[13] This technique relies on exclusion of the aneurysm rather than replacement. Advantages include reduced morbidity and mortality rates and a shorter postoperative stay in hospital. Disadvantages include cost, the now receding concerns over the reliability of new technologies, the need for long-term device surveillance and the high incidence of often minor problems that nonetheless require reintervention.[8] Preoperative assessment of the aneurysm morphology and the aortic dimensions at the neck and distally are crucial. A variety of devices and systems are marketed. Larger delivery systems require exposure of the common femoral artery, but there are now low-profile products that can be delivered percutaneously. The procedure is undertaken under radiological control. In summary, following cannulation an initial angiogram is performed, demonstrating the origins of the renal arteries and confirming the morphology at the neck of the aneurysm. The main body of the stent graft and ipsilateral limb are then delivered and deployed, followed by the contralateral limb (Figure 7.9). It is routine to perform balloon angioplasy to the stent graft landing sites in order to mould the device and improve conformity to the native vessels.

Initially, this technique was limited to the infrarenal aorta, but with the accumulation of experience and the evolution of stent graft technology, including suprarenal fixation and fenestration, the boundaries are extending. It is outwith the scope of this chapter to discuss this topic in much more detail, not least because the exact sequence of deployment is device specific and each has its own idiosyncrasies.

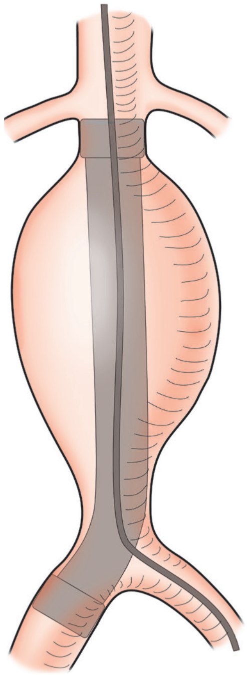

Figure 7.9 *Endovascular aneurysm repair. One component of the stent graft is already positioned. The guide wire is in place through the left iliac system and the second component will be delivered over this.*

Aortic graft complications

The true rate of graft complications is not known but it is estimated that approximately 1–2 per cent of aortic grafts will become infected. This may present as a systemic illness due to sepsis or as a local graft problem, whether in the form of a pseudoaneurysm or the development of a sinus discharging pus from an anastomotic site (most frequently in the groin). More dramatic manifestations include fistula formation or haemorrhage due to anastomotic disruption. Aorto-enteric fistulae are considered part of the spectrum of infective complications; the graft is inevitably infected at the point at which the condition becomes apparent. The aetiology is considered by many to be infection, and the treatment options are similar.

Diagnosis of graft infection is often difficult. If the patient presents with torrential gastrointestinal bleeding, sepsis or with an obvious septic focus and a CT scan demonstrates perigraft fluid, ectopic gas or intravenous contrast medium in the bowel lumen, the diagnosis is simple. However, it is much more difficult to exclude or confirm graft infection in a patient with more insidious symptoms; for example, weight loss, lethargy, pain or gastrointestinal blood loss. CT scans may show focal bowel thickening, inflammation of the perigraft tissues or minor anastomotic dilatation, but none of these alone will secure a diagnosis. Labelled white cell scans and magnetic resonance imaging (MRI) have a role, but reported sensitivities vary widely. Upper and lower gastrointestinal endoscopy is often unhelpful unless there is active bleeding, but an ulcer in the third or fourth part of the duodenum should be treated with suspicion. The patient may present many years after the original surgery, and the bacteria implicated range from a destructive *Staphylococcus aureus* to a low-virulence *Staphylococcus epidermidis*.

Operatively there are two aims: (1) the excision of infected material and septic foci, and (2) the maintenance of tissue perfusion. The mortality of surgery for infected aortic prostheses is reported at up to 50 per cent, with major amputation rates in the survivors also approaching 50 per cent. A major concern is recurrent infection in a newly implanted prosthesis, by either direct or haematogenous seeding.

Occasionally, a local procedure can be performed. The limb of an infected, aortic bifurcated graft can be excised, and this may be sufficient if the patient presented with a chronic local problem. Some surgeons advocate that if any part of a graft is infected, it must be assumed that the whole is affected. Pragmatically, an elderly or frail patient may survive a local graft excision and, if the infection is low grade, there may not be a further problem within that patient's lifetime.

There are three key areas to consider preoperatively:

1. The method of reconstitution of flow must be decided – anatomic or extra-anatomic (Figure 7.10). The extra-anatomical route has the possible advantage of lowering the risk of infection in the new graft. Axillofemoral bypass is described in the section on limb salvage surgery below.
2. The material for the replacement conduit must be chosen – prosthetic material, prosthetic material with microbial retardant adjuvant (e.g. rifampicin or silver coating) or autologous vein. The LSV is not ideal for this purpose, but a graft can be fashioned using the deep venous system of the thigh. Symptomatic chronic venous insufficiency affects only a minority of patients if the profunda femoris vein is left intact. A small number of surgeons have reported work using arterial allografts.
3. Consideration should be given as to whether the procedure can be staged. This is more likely to be possible if the original indication was for occlusive disease many years before and the collaterals are sufficiently well developed. After excising the infected material and closing the defects in the native vessels, a period of careful observation may demonstrate viable limbs fed by collaterals. The graft has been excised and no replacement conduit has been inserted. A delayed replacement bypass can be considered if a limb remains viable but still ischaemic.

If an infected aortic graft is excised and is followed by an extra-anatomical replacement graft, the stump of the proximal native aorta must be closed. This is a vulnerable end closure of a large artery that has a wall made friable by both the underlying degenerative disease and the infection. Monofilament mattress sutures are usually recommended before the aortic clamp is released, followed by a further continuous suture. Distally, the iliac stumps must also be oversewn (Figure 7.10b). The exact sequence of events is variable. Haematogenous seeding and cross-contamination are major hazards regardless of whether the extra-anatomical bypass is done before or after the excision. Opening the axillofemoral component before the aortic flow is closed may lead to occlusion of the new conduit because of competitive flow. There are no solutions without drawbacks.

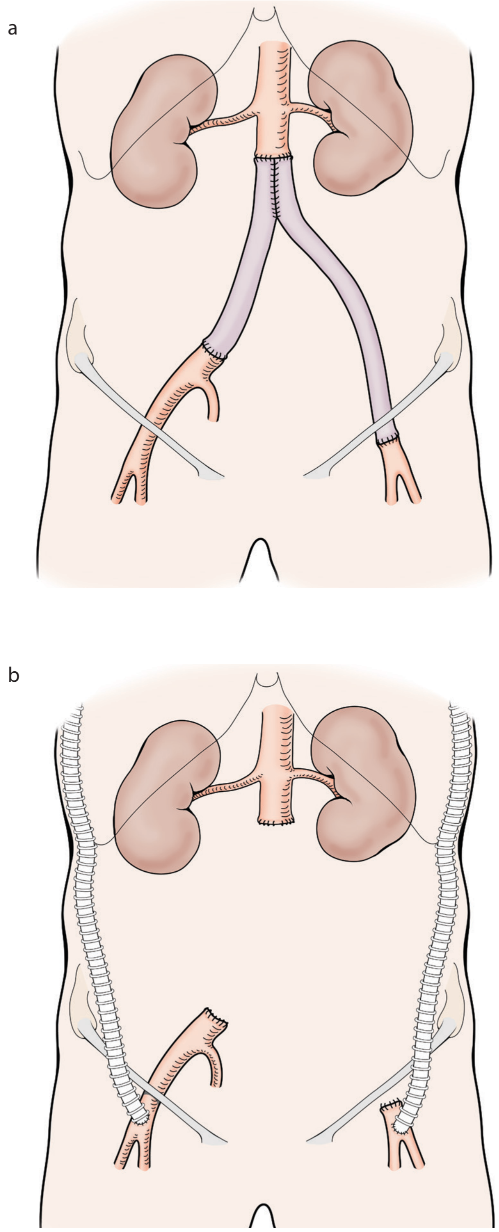

Figure 7.10 *Reconstruction for infected aortic grafts. (a) The infected graft has been excised and replaced with a deep vein graft to the common iliac artery (on the patient's right) and to the common femoral artery (on the patient's left). (b) After excision of the infected aortic graft, the aortic stump and the right common iliac artery have been oversewn. Bilateral axillofemoral grafts can restore distal perfusion.*

THORACOABDOMINAL ANEURYSMS

These aneurysms are subdivided into types I to IV and are illustrated diagrammatically in Figure 7.11. The nomenclature is superficially confusing, as type IV aneurysms are still confined to the abdominal aorta. However, the additional technical challenges they pose justify their inclusion with the other thoracoabdominal aortic aneurysms (TAAAs).

The surgery for any of these aneurysms is a very major undertaking, with significant mortality and morbidity. In many elderly and frail patients surgical intervention will not be justified. Only a few surgical teams undertake these cases, but it is still important that the technical and physiological challenges are understood by those dealing with more common vascular problems, if only to explain to their patients why they need referral to another centre and why their operation is a major undertaking.

The access required to the chest is in itself associated with significant postoperative respiratory sequelae. However, cross-clamping above the visceral vessels is also responsible for the increased complication rate. The ischaemia reperfusion effect is a major insult, so immediate or delayed cardiac complications are frequent. Other specific organ complications, more frequent with the extended nature of TAAA repair, include renal failure, spinal cord ischaemia and coagulopathy. Temporary shunts to maintain distal blood flow have been employed in attempts to reduce left ventricular strain, acute tubular necrosis and paraplegia, but these have not been universally successful. Left heart bypass is also used to maintain distal perfusion if segmental clamping is employed. The proximal anastomosis can be performed with clamps on the aorta at the diaphragm and at the junction of the aortic arch and descending aorta. Meanwhile, inflow from the left heart bypass to a femoral artery maintains perfusion to the lower half of the body by retrograde flow.

Although the aneurysm sac is opened and the top end of a long prosthetic graft is secured in place in a similar fashion to that employed in an infrarenal aneurysm repair, there is the additional challenge of restoring inflow to the important branches of the thoracic and abdominal aorta. Intercostal arteries may have to be reimplanted to safeguard the spinal cord, followed by reimplantation of renal and visceral arteries. Patches of native aorta are cut to encircle the origins of the arteries and these patches are sewn into similar-sized holes cut in the graft (Figure 7.12).

Customised endovascular stents have been developed for the treatment of TAAAs, with fenestrations and branching systems. Endovascular stent treatment can also be combined with open visceral and renal revascularisation in a hybrid procedure to exclude the aneurysm and reroute visceral perfusion.

OCCLUSIVE DISEASE OF THE VISCERAL ARTERIES

Renal artery ischaemia

Occlusive disease of the renal arteries may be atherosclerotic or the result of conditions such as fibromuscular dysplasia. The renal ischaemia may result in deterioration of renal function or may cause renovascular hypertension by altering

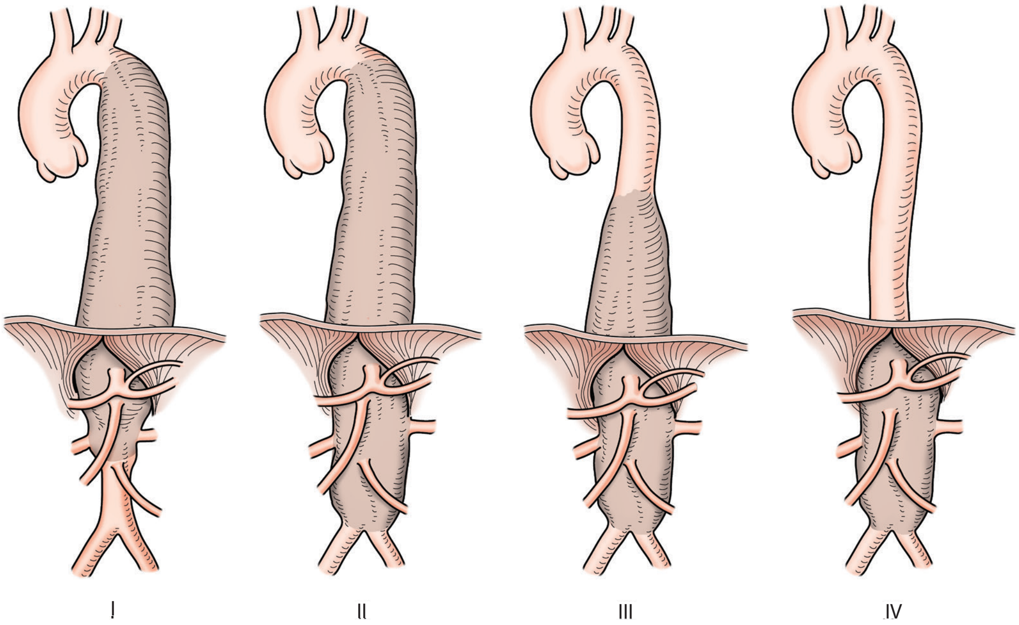

Figure 7.11 *Thoracoabdominal aneurysms are classified into four types. Type I is a thoracic aneurysm that extends down to involve the origins of the visceral vessels. Type II is a diffuse aneurysm involving the whole of the thoracic and abdominal aorta. Type III involves the whole abdominal aorta but only the lower thoracic aorta. Type IV involves the suprarenal portion of the abdominal aorta, but the aorta is normal above the diaphragm.*

the renin/angiotensin homeostatic balance. Renal revascularisation, whether surgical or radiological, now has very few clear indications, namely, recurrent (flash) pulmonary oedema in the presence of bilateral renal artery disease, a tight renal stenosis to a single functioning kidney and renovascular hypertension refractory to medication and associated with deteriorating renal function.

ENDARTERECTOMY

A transaortic renal endarterectomy, as illustrated in Figure 7.13, is a satisfactory approach that is usually possible without a full aortic cross-clamp. The incision is transverse and extends into the renal artery. Closure is with a vein patch. Transaortic renal endarterectomy is useful for ostial disease, but this condition is probably better treated endovascularly by angioplasty and stenting.

BYPASS

The choice between infrarenal and suprarenal aorta as the donor site depends mainly on the distribution of aortic atheromatous disease. An end-to-side aortic anastomosis is best performed with a side clamp, but as this requires a soft vessel, a cross-clamp is needed for the usually thickened and atheromatous aorta. The distal anastomosis of graft to native renal artery beyond the stenosis may be end-to-side or end-to-end (Figure 7.14).

When the abdominal aorta is too heavily diseased for a graft to be taken from the region of the kidney, there are several alternatives. Although the iliac arteries are frequently similarly affected, a soft area can often be found to allow a long graft to be taken up to the renal artery. Alternatively, a graft can be taken from the hepatic artery or, after a splenectomy, the splenic artery can be anastomosed end-to-end to the renal artery (Figure 7.15). A further option is to autotransplant the kidney into the iliac fossa. This will require an arterial and a venous anastomosis, but the ureter, after mobilisation, can be left undisturbed.

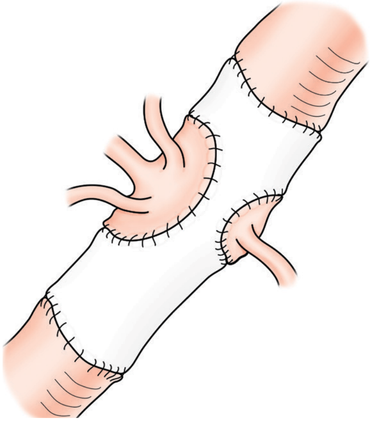

Figure 7.12 *Discs of native aorta are cut to include the origins of the renal and visceral arteries. These discs are anastomosed into holes cut in the graft.*

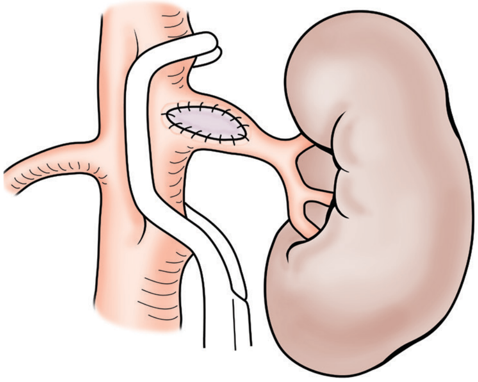

Figure 7.13 *A renal endarterectomy. A side clamp is maintaining distal flow. Closure is with a vein patch.*

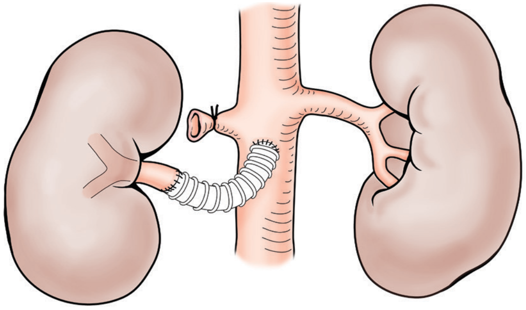

Figure 7.14 *Revascularisation of the kidney with a graft from the infrarenal aorta. This is an end-to-side anastomosis onto the aorta, but an end-to-end anastomosis to the renal artery distal to the stenosis.*

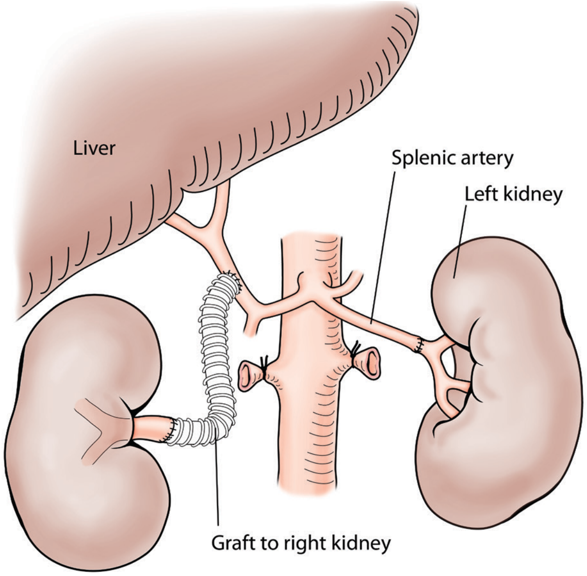

Figure 7.15 *Alternative donor arteries can be used to revascularise a kidney. Right kidney: a graft has been taken from the hepatic artery. Left kidney: the spleen has been removed and the splenic artery itself used for an end-to-end anastomosis.*

SIMULTANEOUS AORTIC AND RENAL ARTERY RECONSTRUCTION

This more major procedure, with a significantly higher mortality rate, may be considered when there is significant aortic pathology also justifying surgery (Figure 7.16).

Mesenteric ischaemia

Acute mesenteric ischaemia, presenting as an intra-abdominal emergency with ischaemic or infarcted bowel, is also discussed in Chapter 23. However, there is considerable overlap between the pathology of acute and chronic presentations. An appreciation by the gastrointestinal surgeon of the causes and treatment of small bowel ischaemia is essential if a patient is to be offered the chance of reperfusion and salvage of sufficient bowel to avoid lifelong parenteral nutrition. Acute presentation may be the result of an embolus to the superior mesenteric artery (SMA), which can be treated by embolectomy, as described in Chapter 23. More frequently, the lesion is thrombosis on a pre-existing lesion.

Chronic mesenteric ischaemia classically presents with non-specific post-prandial abdominal pain and weight loss. Diagnosis depends on an initial suspicion followed by vascular investigations. Occlusions are almost always segmental and multiple. Initially, anatomical communication between the three visceral arteries provides adequate alternative routes for perfusion (Figure 7.17), but once symptomatic mesenteric ischaemia develops, revascularisation must be considered.

As with all revascularisation, the first choice is between radiological intervention and surgery; sometimes a combined approach is appropriate.[14] Stenosis may be primarily at the origin of an artery and this ostial disease in the SMA is a good target for angioplasty and stenting. However, the diaphragmatic crura make the coeliac trunk more prone to reocclusion than the SMA, even when the vessel is stented. Despite this, percutaneous intervention remains a reasonable first option for this vessel. Extensive or more distal disease within the mesenteric vessels invites a surgical approach. Decisions must be made regarding the site for inflow and the target vessels for reperfusion. The type of conduit and the route of the conduit tunnel must also be chosen. The IMA is rarely grafted, except following aortic surgery; the usual target vessels are within the SMA and coeliac systems.

In a purely elective setting, two-vessel grafting is probably preferable. A prosthetic bifurcated graft from the common or external iliac artery is tunnelled through the retroperitoneum in front of the aorta. One limb is then passed up through the small bowel mesentry to the SMA, with a long ‘lazy’ loop, and the other limb is brought up to the coeliac system behind the pancreas. Figure 7.18 shows such a graft taken to the SMA alone. The choice of outflow vessels is based on the preoperative angiograms, but also to a large extent on which patent vessels are accessible. If there are no inflow sites distally, the aorta just proximal to the diaphragm is an alternative.

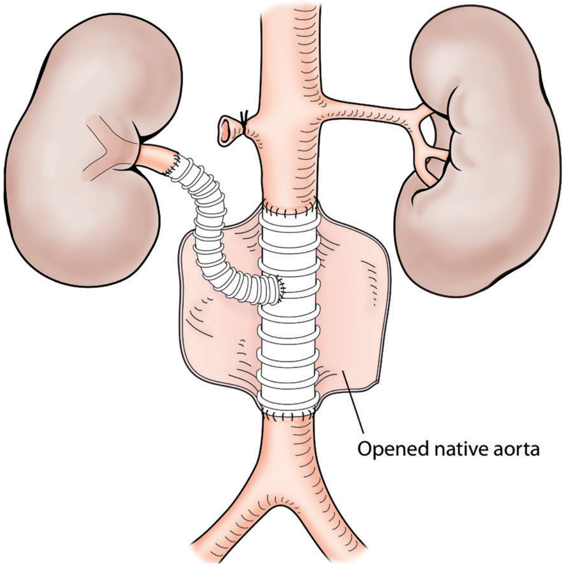

Figure 7.16 *Right renal revascularisation has been combined with an infrarenal aortic tube graft.*

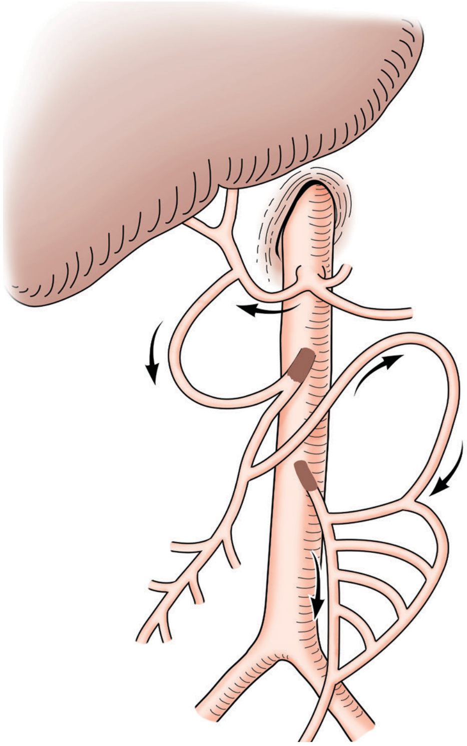

Figure 7.17 *Extensive collateral circulation allows the whole gut to be perfused through a single patent visceral artery.*

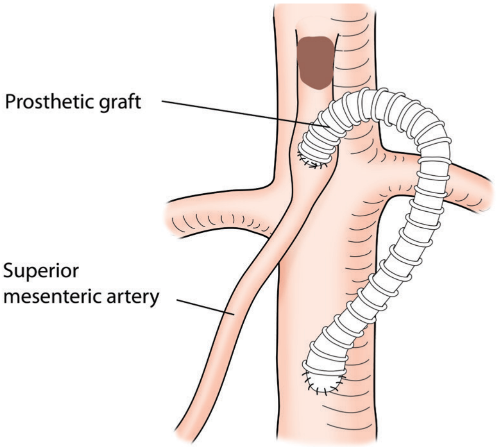

Figure 7.18 *A retrograde bypass graft from the aorta to the superior mesenteric artery. The wide curve reduces the risk of kinking and aligns the flow with the recipient vessel.*

In an emergency the situation is complicated by the need to excise non-viable bowel, or the likelihood that this may be required at a second laparotomy (see also Chapter 23). Prosthetic material is thus contraindicated and vein grafts are required. It is common practice to reperfuse the SMA alone in an emergency. In some acute circumstances, following an angiogram, a combined procedure may be appropriate: radiological revascularisation can be followed by a laparotomy to inspect and manage any necrotic bowel. Additionally, it should also be remembered that some SMA lesions are more easily dealt with by retrograde angioplasty from inside the abdomen once it has been confirmed that there is some hope of salvage.[15]

ACCESS

The visceral arteries are usually isolated via a transperitoneal anterior abdominal approach. The *coeliac artery* is reached by an incision into the lesser sac through the lesser omentum. The aorta emerges into the abdomen just to the right of the oesophagus, which is easily identified if a nasogastric tube has been passed. The origin of the coeliac artery is very close to the diaphragm, and additional aorta above it can be exposed by an incision in the right crus of the diaphragm (see Figure 6.21, p. 103). The origin of the *superior mesenteric artery* can be reached by the same approach as that required for the coeliac artery, but it can also be exposed several centimetres from its origin, where it emerges from the pancreas. The vascular bundle can be identified between finger and thumb placed either side of the root of the small bowel mesentery.

The alternative posterior approach to all three arteries relies on a medial visceral rotation of the splenic flexure of the colon, spleen and tail and body of the pancreas.

DISEASE OF THE ARTERIES OF THE AORTIC ARCH

Although stenoses of the roots and proximal portions of the large branches of the aortic arch can occur in atheromatous disease, (Takayasu's) arteritis is an alternative underlying pathology. Patients with carotid occlusion may present with neurological symptoms, but many are asymptomatic. Those with subclavian occlusion may present with exercise-related symptoms in the upper limb muscle groups or, rarely, critical ischaemia. However, they may also present with neurological symptoms, particularly dizziness, when the only perfusion of the limb is from retrograde flow down the vertebral artery, with subsequent deleterious effects on cerebral perfusion when exercising the upper limb (Figure 7.19a). This is known as *subclavian steal phenomenon* and is a much more common indication for intervention.

Symptomatic disease is relatively rare and an endovascular approach is the first line of management. Surgery is therefore performed relatively infrequently, and patients who do require

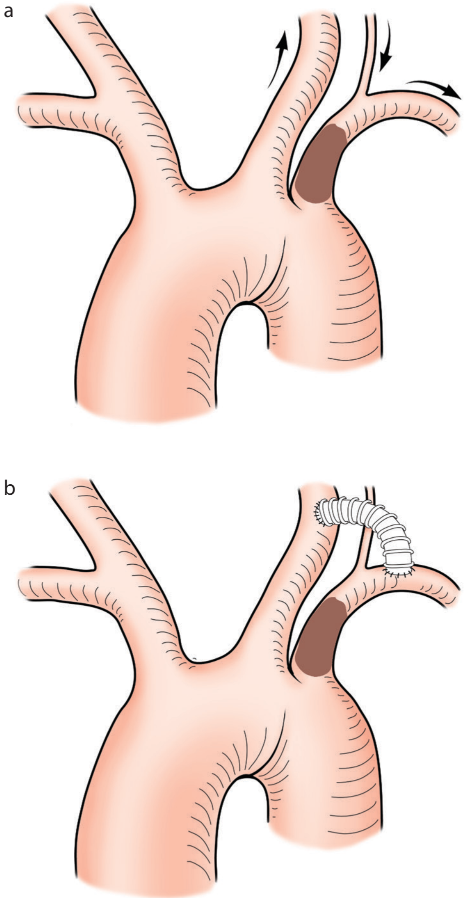

Figure 7.19 *(a) The proximal subclavian occlusion has resulted in 'subclavian steal', in which the upper limb perfusion is dependent on retrograde flow down the vertebral artery. (b) Revascularisation with a bypass graft from the carotid artery.*

operations are usually referred to surgeons with a special interest. However, the principles are similar to other reconstructive challenges. When several vessels are involved, inflow may have to be taken from the aortic arch (Figure 7.20) but if the stenosis affects only one or two large arteries, extrathoracic bypass techniques will be practical. Two such grafts are illustrated in Figures 7.19b and 7.21. In Figure 7.19b a graft has been taken from the common carotid artery to the patent portion of the ipsilateral subclavian artery distal to the obstruction. The supraclavicular approach, which allows simultaneous access to both these arteries, is described in Chapter 6 and illustrated in Figure 6.17 (p. 100). Figure 7.21 illustrates a bypass from a patent axillary artery to a contralateral axillary artery, which has an inflow obstruction. A bilateral infraclavicular approach, as described for an axillobifemoral bypass and illustrated in Figure 7.24, is used. The graft is tunnelled subcutaneously across the anterior chest wall.

OPTIONS IN LIMB SALVAGE SURGERY

The options for limb ischaemia include a conservative approach based on best medical therapy, an endovascular approach, a reconstructive surgical approach, amputation if there is no possible reconstructive option (see Chapter 5), or a palliative approach, accepting that the ischaemic limb is a manifestation of end-stage cardiovascular or malignant disease.

Medical treatment comprises antiplatelet therapy, introduction of a statin and optimisation of antihypertensive therapy. Diabetes should be excluded and, if present, an appropriate regime for glycaemic control introduced. Advice and support should be given regarding cessation of smoking and regular exercise should be advocated.

Endovascular intervention has opened new avenues for limb salvage. Thrombolysis either within a native vessel but, most effectively, within a graft is an alternative to surgery in acute limb ischaemia. Angioplasty, with or without stenting, offers many advantages over surgery, particularly in the aortoiliac segment. Frequently, endoluminal procedures alone are sufficient to salvage a limb. Percutaneous procedures can also be used in conjunction with reconstructive surgery to optimise inflow and allow a crossover graft or a femoropopliteal graft to function. Angioplasty may also salvage a failing graft.

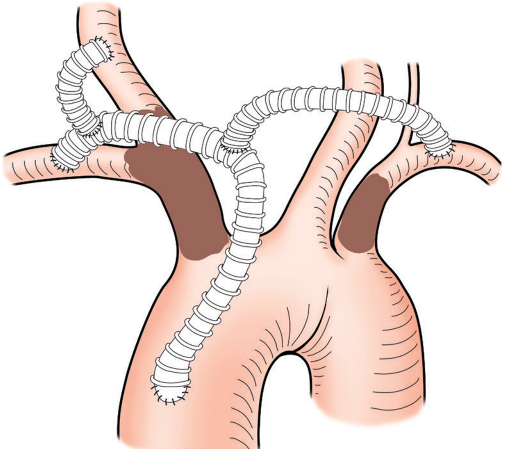

Figure 7.20 *A graft from the thoracic aorta to the arteries of the aortic arch, which are occluded near their origins.*

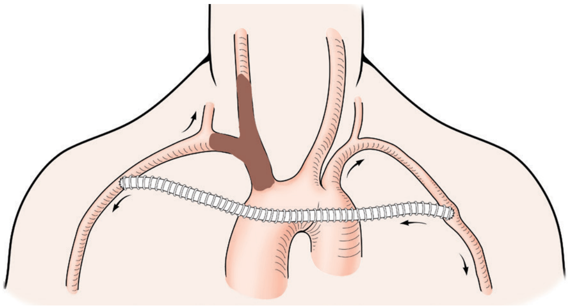

Figure 7.21 *A bypass graft from one axillary artery to the other to restore upper limb perfusion.*

ACUTE LIMB ISCHAEMIA

In the absence of protective collaterals, sudden occlusion of an artery can present as acute limb ischaemia. Limb salvage will usually require emergency intervention to restore distal perfusion. Attempts should not be made to restore the circulation to a limb that is non-viable; not only is this futile, but products from the dead tissue enter the circulation, causing systemic insult including biochemical derangements. Life-saving urgent amputation is occasionally required, but in some patients acute limb ischaemia is a terminal event and palliative care is more appropriate.[11]

Diagnosis and assessment

Classical presentation of acute limb ischaemia is with the six '**P**s': a sudden onset of **P**ain, followed by **P**erishing cold, **P**allor, **P**araesthesia and ultimately **P**aralysis, associated with a **P**ulseless limb. The marble white leg is not seen universally since venous reflux or a trickle of blood via collaterals can colour the skin and confuse the situation. Hand-held Doppler assessment is very helpful, as is a clinical comparison with the pulse pattern of the contralateral limb.When the diagnosis has been established, anticoagulation is commenced with 5,000 IU of unfractionated heparin. Access to theatre is not always as swift as needed and heparin may reduce some thrombus extension.

Consideration of the underlying pathological process is important. Acute ischaemia may result from embolism or thrombosis *in situ* due to underlying atheroma, aneurysm or to a new or acquired thrombophilia. The mechanism of the acute occlusion will influence the surgical salvage strategy, but the value of investigations to clarify this must be balanced against the resultant delay, during which the potential for a good functional recovery is deteriorating. A difficult balance needs to be found if there is suspicion of underlying arterial disease. In this situation several rescue strategies may need to be considered, which makes good preoperative imaging highly desirable. Rapid symptomatic deterioration suggests that the patient has little in the way of protective collaterals and that the limb is imminently threatened. Likewise, sensorimotor impairment increases the urgency of the situation. Consideration should therefore be given to urgent exploration with a view to thromboembolectomy and on-table imaging.

If the onset of symptoms has been more insidious, with a pre-existing history of claudication or even rest pain, reinforced by evidence of contralateral peripheral arterial occlusive disease, preoperative imaging is essential. In this context there may be a role for thrombolysis as the first line in treatment (see Chapter 6), followed by either angioplasty or definitive surgery. The groups of patients for whom lysis may be more suitable include those with graft occlusion, those with multiple emboli arising from a popliteal aneurysm and those in whom there is a specific underlying anatomical abnormality, such as popliteal artery entrapment syndrome. In each of these scenarios, lysis can be used to retrieve a difficult ischaemic situation and allow definitive corrective surgery at a later date. Surgeons must be wary of a patient presenting with a complication of a thrombosed or embolising popliteal aneurysm (see below). Some 50 per cent of patients presenting in such a way will ultimately lose their leg due, at least in part, to a failure of timely diagnosis.

The limitation of thrombolysis in acute limb ischaemia is the delay after the start of treatment before there is any improvement in perfusion. There is often even an initial worsening of both the symptoms and signs of ischaemia in the first few hours. This makes it an unsuitable treatment when the initial assessment indicates limb loss within 4–6 hours unless the circulation is restored.

Thromboembolectomy

The two commonest sites for this procedure are the common femoral artery in the groin and the distal brachial artery just above the elbow. In both cases this represents a site of arterial bifurcation where an embolus may lodge. Usually there is extension of thrombus proximal and distal to the occlusion. All thrombus must be removed before perfusion can be restored. The diagnosis of embolus is more secure in the upper limb. In the lower limb there is a greater likelihood of an iliac or superficial femoral artery thrombosis *in situ*. Thrombectomy may be successful in this situation but, if it does not succeed in restoring distal perfusion, there may be a need for a salvage bypass.[16]

BRACHIAL EMBOLECTOMY

Many surgeons will treat brachial emboli conservatively with anticoagulation alone, especially in the frail group of patients in whom this condition often presents, but review every few hours is an essential component of conservative management. Inadequate return of power to the dominant hand is the most frequent indication for a delayed salvage pocedure.

Embolectomy can be performed under local anaesthesia in a cooperative patient and most patients tolerate this well, but it is advisable to have an anaesthetist present, as an acute deterioration can occur during the procedure and sometimes some sedation or conversion to a general anaesthetic is required. Often a pulse can be felt all the way down the brachial artery to just above the bifurcation in the antecubital fossa. This is the site to infiltrate with 10–15 ml of 1 per cent lidocaine, in the anaesthetic room, before scrubbing. If a pulse is not felt over the brachial or axillary arteries, preoperative imaging is strongly indicated.

The arm, positioned in abduction and lateral rotation, is supported on an arm board. The skin should be prepared from the shoulder to the wrist, and the hand is draped in such a way as to allow assessment of the return of perfusion (a clear bowel bag is useful if available). A lazy-S incision is made from just medial to the distal portion of the biceps muscle, over the tendon and then down onto the forearm. After incising the skin, a few subcutaneous veins are usually encountered; these should be divided between ties or pushed to the side with a self-retainer. The brachial artery lies between the biceps tendon and the median nerve and deep to the bicipital aponeurosis. The latter structure can be incised to allow further exposure (see Figure 6.20, p. 102). The brachial artery is slung and this can be used to retract it forwards to find the bifurcation. Both the radial and ulnar arteries must be slung to allow proper clearance of these vessels. The interosseous artery often arises close to or at the bifurcation and may produce troublesome back-bleeding.

The arteries are clamped and a transverse arteriotomy is performed about 1 cm proximal to the bifurcation. A Fogarty balloon is passed, proximally first and then distally, down both the radial and the ulnar arteries. Good inflow must be established, as well as good back-bleeding from each of the distal vessels. The Fogarty catheter must be used with care, as discussed in Chapter 6. It is important not to overinflate the balloon and to adjust the pressure with care as resistance changes: the pressure can be gauged through the thumb depressing the syringe plunger.

Completion angiography is desirable. Ideally, this is achieved with a C-arm image intensifier system. Modern machines can produce subtraction images in theatre.

Once satisfied, the arteriotomy is closed with interrupted 5/0 or 6/0 monofilament sutures, inserted so that the needle passes from deep to superficial on the distal part of the artery.

FEMORAL EMBOLECTOMY

Most femoral explorations can be performed under local anaesthesia. However, a number of cases may require fasciotomies or, occasionally, a bypass, so it is essential that the anaesthetist has seen the patient preoperatively. Once more, it is better to inject the operative field with 1 per cent lidocaine (20 ml) before scrubbing. The groin should be shaved and consideration must be given to the possible need for a crossover graft. The skin of the limb is prepared down to the ankle, after which the foot is placed in a transparent bowel bag. The anterior superior iliac spine and the pubic tubercle should be left visible as useful groin landmarks. The common femoral artery is approached via a vertical or oblique incision through skin and the subcutaneous fat. Scarpa's fascia is incised and, deep to this level, veins and lymphatics must be divided between ties as encountered. The lymphatic channels are commonly visible just anterior to the common and superficial femoral arteries. The common femoral artery is slung at the level of the inguinal ligament and tapes are then also passed around the superficial and deep femoral arteries. Care must be taken not to damage the profunda femoris vein when dissecting the artery. The posterior aspect of the bifurcation must be carefully inspected to avoid missing a 'first perforating branch' of the deep system. Anatomy is variable and the lateral or medial circumflex arteries may arise from either the common femoral or the profunda femoral artery.

Careful attention must be given to the quality of the vessels. The superficial femoral artery may be chronically occluded, the origin of the profunda may be narrowed or there may be a posterior plaque running down into the common femoral artery from the external iliac artery. These features will influence placement of the arteriotomy and clamps. The common femoral artery is opened transversely if the vessels are large and disease-free or if the common femoral disease is confined to a modest posterior plaque. An oblique arteriotomy down into the profunda femoral artery is best if the superficial femoral artery is chronically occluded and the origin of the profunda is hard and therefore in need of patch angioplasty closure. If in doubt, a longitudinal arteriotomy, with planned patch closure, is perhaps the best incision to keep options open. However, a transverse arteriotomy can be converted into a diamond opening to allow a common femoral endarterectomy, patch closure or the anastomosis of a bypass graft.

Inflow must be established first. The iliac system is swept with a large (size 4 or 5) Fogarty catheter. Good inflow, once gained, must be protected by flushing dilute heparinised saline solution (2,000 IU heparin in 500 ml saline) up the iliac system. Occasionally, inflow cannot be established and at this stage consideration must be given to a salvage extra-anatomical bypass or radiological intervention.

Once inflow is established, attention is turned to the distal circulation. A size 3 Fogarty catheter is passed down the superficial femoral artery. In the case of a classic embolus, the major fragment will be found on opening the common femoral artery, but there will be smaller fragments and a ribbon, often an arterial cast, of propagated thrombus down the superficial and profunda femoral arteries. Keep passing the catheter up and down until there is no further return of thrombus and good back-bleeding: the catheter should have been passed to at least 40 cm down the artery. These distal vessels should also be generously flushed with heparinised saline. Completion angiography is desirable, particularly if the clinical result of reperfusion is poor or if the catheter cannot be passed beyond the adductor hiatus. It may be that there is chronic occlusive disease with a stenosis or occlusion in the femoropopliteal segment, or the thrombus may be strongly adherent to the vessel wall. Alternatively, there may be a slightly unusual cause for acute ischaemia, for example a thrombosed popliteal aneurysm or, very rarely, an acute presentation of an entrapment syndrome. In some theatres there is no access to C-arm facility with image intensification. In these circumstances clinical assessment following closure of the arteriotomy is all there is to rely on. Watch for reperfusion of the foot with a marked hyperaemia. An awake patient will often report a return of feeling, movement and warmth.

If thrombus cannot be cleared from the distal circulation, thrombolysis may be considered. Tissue plasminogen activator (t-PA) can be administered directly into the artery. The usual dose is 10 mg made up to 20 ml and instilled for 20–30 minutes before repeating the angiogram. If there is a chronic superficial femoral artery block, collaterals may be well developed. In this situation, clearance of both the acutely blocked iliac system – and of the common and profunda femoral arteries – may be sufficient to restore perfusion to the limb. It is worth closing the arteriotomy and watching what happens to the foot. A patch angioplasty of a narrowed profunda origin may be sufficient to prevent rethrombosis.

Sometimes, a salvage bypass is required, as is performed for chronic ischaemia and described below. Fasciotomies (see Chapter 4) may also be indicated, especially if there was marked calf tenderness or sensorimotor impairment preoperatively. However, hard and fast rules on the need for fasciotomies are very difficult to define. Fasciotomies are not a local anaesthetic procedure and the likely need for them is an indication for a general anaesthetic. Thought should be given preoperatively to these possibilities and the patient consented appropriately. If there is any doubt regarding fasciotomies, then subcutaneous fasciotomies can be a compromise. At the very least the small incisions of subcutaneous fasciotomies will give an indication of reperfusion swelling within the compartment spaces. Most at risk is the anterior compartment.

SADDLE EMBOLI

This is the situation in which a large embolus lodges in the aortic bifurcation, rendering both lower limbs acutely ischaemic. The principle differential diagnoses are of acute in situ thrombotic aortic occlusion and acute spinal cord ischaemia or compression. Diagnosis can be confirmed by CT angiography. It may be possible to clear the embolus by embolectomy via bilateral common femoral access, as illustrated in Figure 7.22, but salvage may require axillofemoral bypass.

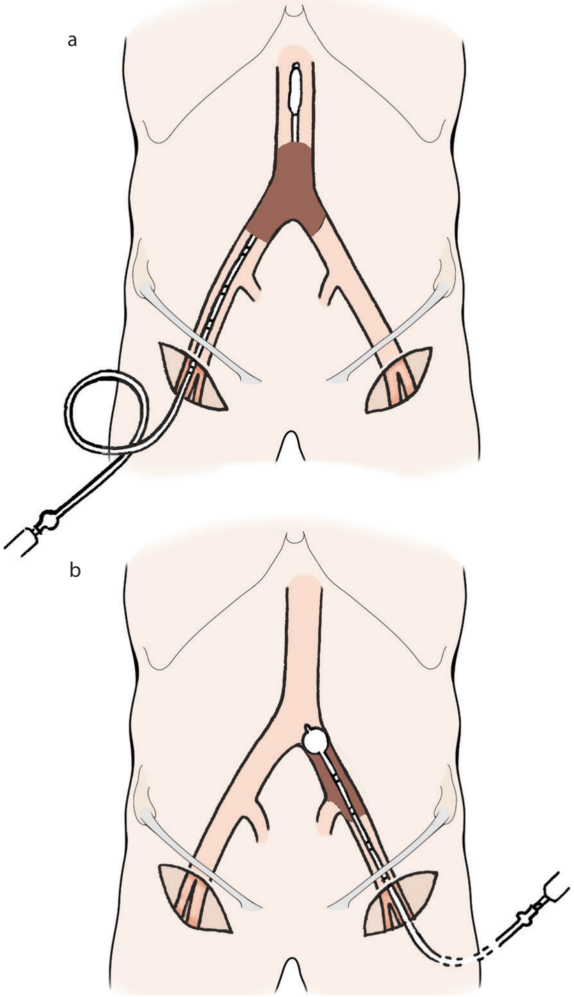

Figure 7.22 *Embolectomy of a saddle embolus at the aortic bifurcation. (a) The catheter tip is above the embolus after introduction through the right femoral artery. (b) The residual clot is then removed via the left femoral artery.*

CHRONIC LIMB ISCHAEMIA AND ARTERIAL RECONSTRUCTION

The management of patients with a chronically ischaemic limb requires a holistic approach, balancing the patient's potential functional capacity and co-morbid conditions against the severity of the limb ischaemia and the level of symptoms. Possible salvage procedures, available autologous bypass conduit and the likelihood of success must also be considered, both before and after imaging. Although a patient with a chronic, non-critical ischaemia is often managed conservatively, there are some circumstances where even operative intervention is appropriate for incapacitating claudication.

Non-critical chronic limb ischaemia usually follows a relatively benign course, with low rates of limb loss or the necessity for salvage intervention. However, a proportion of patients will develop *critical limb ischaemia*. Pragmatically, critical limb ischaemia can be considered to be a limb threatened with loss of viability if left untreated, but it is defined by European Consensus criteria as a chronic situation (>2 weeks), resulting in rest pain and/or tissue loss in the form of ulceration or gangrenous digits. Typically, the ulcers appear over the bony prominences of the foot where skin is stretched or subject to pressure from footwear. The development of sensorimotor signs or calf tenderness (which implies muscle ischaemia) indicates impending limb loss and intervention, either radiological or surgical, becomes necessary if amputation is to be avoided.

It is helpful to think of the lower limb blood supply divided into three segments: the *aortoiliac* segment, the *femoropopliteal* segment and the *distal vessels*. Clinical examination will give a fairly good indication of the segments affected by occlusive disease. As a very general rule, it is unusual for a limb to become critically ischaemic if only one segment is involved. However, if the patient is diabetic, the foot may develop ulceration and web space sepsis in the presence of an arterial tree that is, to all intents and purposes, normal to the level of the distal calf. Also, a patient may develop rest pain or tissue loss if relatively mild arterial disease is compounded by poor cardiac function or collateral pathways have developed poorly.

Adequate imaging is essential before planning salvage procedures. A limb may be dramatically improved by simply dealing with the most diseased segment by radiological or surgical means. The operative strategies by anatomical segment are described below. The technical aspects of endovascular intervention are not discussed further, but these options should be considered, especially in aortoiliac disease, as either a definitive treatment or as a method of improving inflow to allow a more distal bypass. Furthermore, there is evidence that femoropopliteal disease can be managed effectively by an endovascular procedure even in critical ischaemia.[17]

Before concentrating on individual operations, it is helpful to consider the principles governing the choice of procedure, including the conduit and the anatomical route taken to connect the recipient and donor vessels. Essentially, a graft will fail if the inflow is inadequate, the outflow vessels are too diseased or the conduit is inadequate in terms of quality, diameter or material. The most frequently used conduit for infrainguinal bypass is the LSV. If the bypass is only going to the above-knee popliteal segment, a prosthetic material probably produces similar patency and limb salvage rates. However, for longer bypasses it is generally accepted that prosthetic material is inferior. The ipsilateral LSV is usually the preferred option, but other suitable superficial veins include the contralateral LSV, an SSV or an arm vein. A deep system vein, such as the femoral vein, can also be considered.

A graft can be routed in a way that mimics the vessel that it is replacing (an *anatomical bypass*) or in a way that does not (an *extra-anatomical bypass*). Examples of anatomical bypasses include femoropopliteal bypass, the aortobifemoral bypass and the iliofemoral bypass. Extra-anatomical bypasses include femorofemoral crossover grafts and axillofemoral grafts. The reasons for choosing a particular route include the choice of inflow and outflow vessels, the choice of anaesthetic technique and the patient's general health. For example, an axillofemoral graft obviates the need to open the abdomen, and a femorofemoral crossover graft can be performed under regional or even local anaesthesia.

Aortoiliac disease

Aortoiliac segment disease can frequently be managed by endovascular means, and as a result the number of surgical procedures on this segment has fallen significantly over the past 20 years. However, anatomical and extra-anatomical bypasses are still necessary, normally in the context of long iliac system occlusions. The most commonly performed procedures are aortobifemoral grafts, axillofemoral grafts and crossover grafts.

The groin dissection is described above. This is usually performed first to establish that the graft will have adequate outflow. The common inflow sources are the aorta, the axillary artery, the contralateral femoral system or, less commonly, the ipsilateral or contralateral iliac systems. Small modifications of the groin approach may be necessary according to the donor source; for example, the direction of the skin incision and the orientation of the arteriotomy.

AORTOBIFEMORAL BYPASS

In occlusive disease these grafts are performed in a fashion similar to that described above for aneurysms except that many surgeons prefer an end-to-side arrangement in the abdomen. This may be less haemodynamically favourable and more difficult to cover with peritoneum at the end, but maintains the collateral circulation and provides some protection to the limb in the event of graft occlusion (Figure 7.23). This on-lay technique is particularly advantageous if it allows preservation of flow into a patent IMA. In many cases of aortic occlusion, the graft itself may be sited lower down the aorta than the angiogram first suggests. The top part of the occlusion often comprises fairly fresh thrombus that can be pulled out like a champagne cork using a Fogarty catheter. This is likely to be the case if the level of the occlusion extends up to the origins of the renal arteries and the aorta feels soft.

AXILLOBIFEMORAL BYPASS

The advantage of the axillobifemoral bypass relates to the level of surgical insult to which the patient is subjected. No major muscle groups are incised, the abdomen is not opened and the aorta is not clamped. Axillofemoral grafts also have a role when there is a need to avoid a site of infection in the abdomen. Before surgery it is wise to check that the donor artery is disease free. Measuring the blood pressure in both arms can be enough, but many prefer the reassurance of a duplex scan to confirm normal flow patterns.

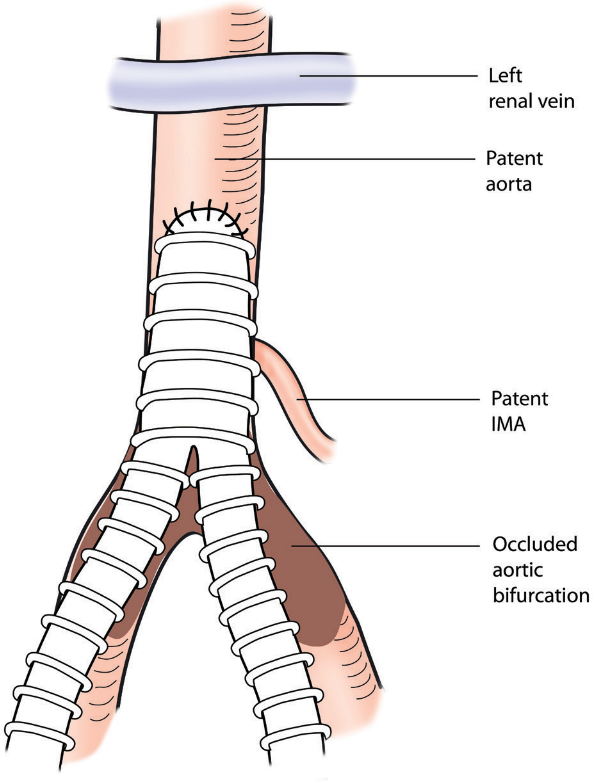

Figure 7.23 *An end-to-side anastomosis may be preferred in an aortobifemoral bypass for occlusive disease. The inferior mesenteric artery (IMA) can be preserved and, if patent, this maintains some antegrade flow to the pelvic organs. In the event of graft failure, the limbs may also be partially protected by collaterals.*

Surgical opinion is divided as to whether access is better with the arm in abduction or by the patient's side. An approach to the axillary artery is illustrated in Figure 6.18 (p.101). However, as only limited access is required for this procedure, a smaller transverse incision, extending from 1–2 cm below the central portion of the clavicle to a point just below the medial limit of the deltopectoral groove, will suffice (Figure 7.24). Once through the skin, the pectoral fascia is encountered. This fascia and the underlying pectoralis major muscle are incised along the lines of the fibres and held open with a self-retaining retractor. Deep to this is the clavipectoral fascia, which is incised. In so doing, a free edge of the pectoralis minor is exposed. This muscle can be retracted, divided at this stage or divided later. The pulsation of the axillary artery can usually now be felt clearly. The artery and vein are closely related, the artery running slightly superior and deep to the vein. Tributaries to the vein can be ligated and divided. The artery must be slung with great care, as this is a very soft vessel and can easily be torn or branches avulsed. It may be advisable to ligate the minor branches, especially those arising posteriorly, to prevent back-bleeding when the vessel is opened. Passing a sling around the artery as soon as it is safe will allow application of some gentle traction, which will be helpful during the more distal dissection.

The tunnel should be created before heparin is administered. This is done by first running a finger deep to pectoralis major and onto the chest wall. If the graft is only to one groin, then it is often possible to push the tunnel device from here all the way to the groin. The graft should run in the mid-axillary line before being directed medially to pass in a gentle curve, medial to the anterior superior iliac spine (see Figure 7.10b). If the groin is infected, the graft can be directed laterally for longer to allow passage through healthy subcutaneous tissue to the superficial femoral or mid-thigh profunda artery. If the graft is to go to both groins, an additional incision is often helpful. The surgeon has the choice here of using a commercially prepared bifurcated graft or suturing a crossover piece to pass from the groin, or higher, to the other side.

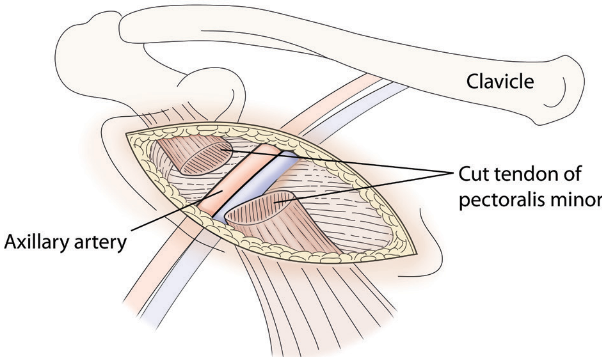

Figure 7.24 *A small transverse infraclavicular incision will provide good access to the axillary artery for an axillofemoral bypass.*

The additional incision allows the crossover portion to be placed carefully without kinking. Tunnelling in the subcutaneous plane of the abdominal wall carries a real risk of entering a body cavity or coming through the skin. It is important that the drapes are carefully placed at the start to allow as much view of the planned track as possible. Urinary catheterisation is advisable to reduce the chances of bladder damage.

The anastomoses at each end are performed in a standard fashion, but it is important to ensure that there is enough length in the graft so that it is not tight even at the extremes of movement of the very mobile shoulder joint.

FEMOROFEMORAL CROSSOVER GRAFTS

This extra-anatomical bypass can be performed quickly under regional anaesthesia. The groin dissections are performed as described above. The graft is tunnelled subcutaneously just above the pubis (Figure 7.25a). Sometimes, it is helpful to arrange that each arteriotomy is slightly oblique so that the graft lies in a gentle curve. Again, care must be taken during tunnelling; the abdominal wall and even the bladder can be penetrated, especially in patients with previous abdominal surgery. Preoperative urinary catheterisation is advised.

ILIOFEMORAL BYPASS

This is very similar to the femorofemoral graft, except that the common or external iliac artery is used as an alternative inflow (Figure 7.25b). The approach to the iliac arteries is by

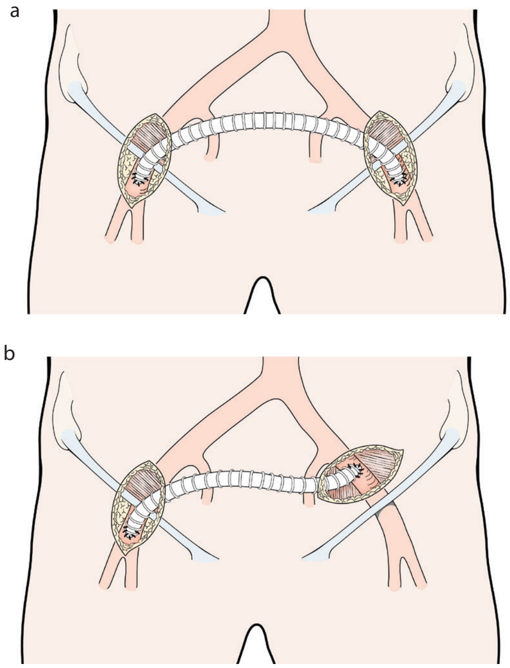

Figure 7.25 *Crossover grafts. (a) Femorofemoral. (b) Iliofemoral.*

retroperitoneal dissection through a muscle-splitting incision. The external oblique aponeurosis is split first, up to the edge of the rectus sheath. The internal oblique and transversus muscle fibres are then split to reveal the peritoneum, which is swept up by blunt dissection. The retroperitoneal vessels are exposed and the arteries are easily dissected if this is an untouched field. The graft can be run out through the corner of the wound to the contralateral groin, or under the inguinal ligament for an ipsilateral graft.

Femoropopliteal segment disease

The patient with chronic, severe lower limb ischaemia affecting the femoropopliteal segment usually has a superficial femoral artery occlusion extending from its origin to the above-knee or, more commonly, the below-knee popliteal segment. Well developed collateral channels from the profunda system may be sufficient to allow minimal, or indeed no, symptoms from a short femoropopliteal occlusion. However, disease progression either in the segment above or below, or involving the common femoral or profunda vessels, may result in severe claudication, progressing to critical limb ischaemia. Despite recent advances in therapeutic endovascular intervention, there remains a role for infrainguinal salvage surgery, particularly in the context of complex lesions or long occlusions in any patient with a life expectancy estimated at greater than two years.[17]

As always, adequate imaging is key to the assessment of inflow and run-off. Ideally, there should be at least one complete vessel running out of the below-knee popliteal. In the face of probable amputation, some surgeons will still perform a bypass into a 'blind' popliteal segment, relying on a bed of collaterals or incomplete calf vessels to perfuse the leg. However, this option is rarely taken as bypass to the distal vessels of the calf is effective and durable.

FEMOROPOPLITEAL BYPASS

This bypass, shown diagrammatically in Figure 6.12 (p. 92), is the standard operation for femoropopliteal occlusive disease. The patient is positioned supine and the limb prepared from the level of the umbilicus down to the ankle. If the foot can be placed in a clear bowel bag, this facilitates assessment of perfusion following revascularisation. The leg must be free enough to allow repositioning during the procedure. The recipient artery should be dissected first, to confirm that a bypass is possible. The common femoral artery is then isolated by a standard groin dissection, modified by an angled incision to allow additional access to the LSV. After both the inflow and outflow vessels are exposed, the tunnel for the graft should be made prior to the administration of heparin.

Exposure of the above-knee popliteal artery is achieved through a medial incision starting level with the upper part of the femoral condyle and extending proximally for 10 cm or so, a hand's breadth behind the patella (see Figure. 6.23, p. 105). This is the surface marking of the LSV. The exploration proceeds through the groove between the vastus medialis muscle mass and the medial hamstrings (semitendinosus and semimembranosus). Sartorius and gracilis are retracted forwards with vastus medialis. The muscles are held apart by a self-retaining retractor. The popliteal fossa at this level is often quite fatty and the artery is found on the underside of the femur, having just passed through the adductor hiatus. The artery and vein are easily separated and, when mobilised, the popliteal artery can be brought to the surface. There are usually large genicular branches, which should be protected and preserved.

Exposure of the distal segment of the popliteal artery is also most commonly approached from the medial side. The skin incision is placed parallel and 1 cm posterior to the medial subcutaneous border of the tibia. The exposure is easier to perform if the knee is bent to 90 degrees and the hip is flexed and abducted as much as the joint will allow. The LSV often lies directly under these markings, and there is frequently little subcutaneous fat to protect against damage at the time of skin incision. It must be freely mobilised and protected, and the medial head of the gastrocnemius is then retracted posteriorly, if necessary dividing some of the dense fascia connecting it to the tibia. The plane between the bone and muscle is opened to enter the distal popliteal fossa. Occasionally, the insertions of the tendons of semitendinosus, semimembranosus and gracilis restrict access (see Figure 6.23, p. 105). Some authorities advocate division of these structures, but space can usually be gained by full mobilisation and retraction of the tendons. The artery is lateral to the vein, which may be single or a pair, and must be separated with some care, as venous bleeding at this stage can be difficult to control. If the popliteal artery is soft and suitable for the anastomosis, it may be enough to restrict the dissection to the true popliteal vessel. However, the proximal part of this arterial segment is often heavily diseased and it becomes necessary to place the arteriotomy more distally. Mobilising the region around the popliteal division requires division of the anterior tibial vein to allow access to the anterior tibial artery and tibioperoneal trunk (Figure 7.26). Clamping these vessels with a light bulldog clamp can be difficult and sometimes it is necessary to double-loop and tighten the slings, with or without the use of a vessel occluder.

Vein graft

The LSV can be used either *in situ* or as a free reversed graft. In either case, the broad proximal segment of the LSV makes an ideal hood in terms of both size and shape for an anastomosis. For this reason the LSV must be divided as close to the common femoral vein as is safe, using a Satinsky clamp to maximise the length of the vein graft (Figure 7.27). All tributaries of the LSV must be accurately ligated with a 1 mm stump length. Care must be taken not to impinge on the vein by catching the adventitia in a knot and kinking the graft.

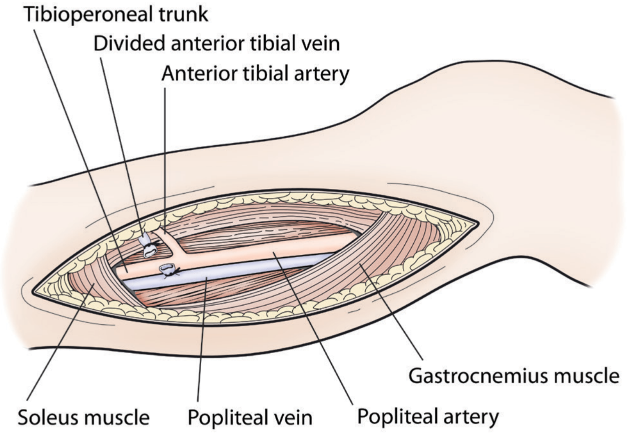

Figure 7.26 *Medial approach to the below-knee segment of the popliteal artery. Note the divided anterior tibial vein, which has increased distal access and enabled the tibioperoneal trunk to be isolated.*

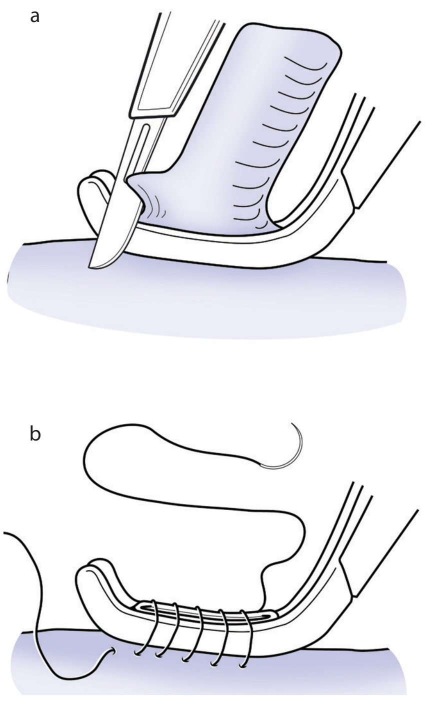

Figure 7.27 *A technique for dissecting the saphenofemoral junction and maximising the length of the graft without compromising the lumen of the common femoral vein. (a) A clamp is applied at the junction and the vein cut flush against it. (b) The common femoral vein is closed by suturing over the clamp. This suture is left loose and then the clamp is wriggled free, before returning with a second row of stitches to tie the suture to itself.*

***In-situ* grafts**. This technique has the advantages of size-matching the vessels and vein handling, with potential for trauma, is minimised. However, if the saphenofemoral junction is significantly lower than the first soft portion of the common femoral artery, the LSV must be mobilised for some length down the thigh to allow a tension-free proximal anastomosis. Sometimes this is not possible at all. Disadvantages of *in-situ* grafts include the need to deal with the valves and the action of passing a valvulotome to destroy the valve cusps can damage the graft intima or even slice open the vein. Each tributary is also a potential fistula.

After completing the proximal anastomosis the femoral artery clamp can be released. This allows some flow down the vein graft as far as the first competent valve, and also allows the profunda system to perfuse the limb. The valvulotome is then passed up from the distal end of the vein, through a small venotomy before dividing the distal end of the vein, or up the lumen of the free end if the vein has already been divided. The valvulotomy device must be passed several times, rotating it through 90 degrees each time. Care must be taken when passing the device to minimise intimal trauma. The valvulotome can also tear the vein and disrupt the proximal anastomosis. The latter can be protected by the assistant pinching the graft closed just distal to the anastomosis.

There are several methods of identifying the tributaries, which must all be ligated. The whole length of the vein can be exposed for direct inspection. Alternatively, if an on-table angiogram is performed, a tape with radiopaque markers can identify the site of tributaries, allowing targeted incisions. A third option is to expose the vein through a series of short skip incisions. A hand-held Doppler probe is then applied in turn to each segment of exposed vein, which is pinched closed just distal to the probe. If flow can be heard, there must be a patent more proximal tributary, which is then identified and ligated. This process is repeated until the distal end of the graft is pinched and no flow is detected.

Free reversed vein grafts. The vein must first be harvested, reversed and tested. Preoperative duplex marking of the vein will indicate its course, distal diameter and sites of confluence. The vein can be harvested and tributaries ligated through a single long incision or through a series of interrupted or skip incisions. The latter approach takes longer, but may reduce wound complications. It is important not to cut obliquely onto the vein as undermining increases the risk of skin necrosis and other wound complications. The proximal end of the vein is divided at the saphenofemoral junction, as described above, but the distal end of a free graft is best not divided until the arteriotomy sites at both ends have been decided. This may mean waiting until arteries are opened, as further vein length may be needed. The harvested vein is tested by gentle distension with heparinised saline: overdistension will damage the adventitia. Small holes, caused by the avulsion of tiny tributaries, may require repair with figure-of-eight stitches, but these must be placed so that they do not narrow the vein.

Prosthetic grafts. A prosthetic graft may have to be used if there is no suitable vein. This a satisfactory alternative if the graft does not have to be taken to below the knee (see also Chapter 6).

Tunnelling

The graft can be tunnelled through a relatively anatomical pathway (which may be the best option for a synthetic graft) or placed superficially within the bed of the LSV (which is probably the best option for a vein graft). Some surgeons employ a combination of routes when bypassing onto the below-knee popliteal artery, leaving the vein superficial in the thigh but bringing it through the popliteal fossa from above to improve the angle and reduce the risk of graft kink by the hamstring tendons. The most important pitfall to avoid while tunnelling is a graft twist. One strategy is to release the clamp on completion of the proximal anastomosis and allow pulsatile flow through the graft. If the graft is twisted or kinked, it is often evident on inspection, but simply allowing forward flow through the graft may allow it to untwist if it has sufficient space to do so. If a hollow tunnel device is used, this has the advantage of providing space.

Anastomoses

End-to-side anastomoses are usually performed and the techniques have been discussed in Chapter 6. The popliteal anastomosis can be difficult because of both restricted access and the size of the vessels. A clip on the redundant vein beyond the toe is helpful (Figure 7.28) and a parachute technique works well, allowing precise placement of each suture.

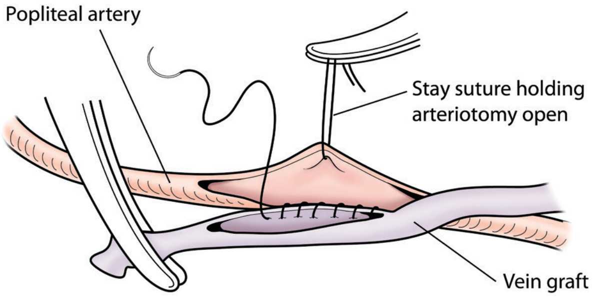

Figure 7.28 *Popliteal anastomosis. A stay suture holds the artery open, making the suturing of the far side of the anastomosis easier. The vein graft is held by mosquito forceps, but this damaged portion of vein will be excised to shape the toe of the graft.*

Distal bypass

The success of revascularisation surgery is dependent on adequate outflow. On occasion the only outflow may be through a single crural vessel. Fortunately, these are relatively easy to access surgically.

Anterior tibial artery

The anterior tibial artery is most commonly exposed in the middle or distal third of the calf. The incision is made halfway between the lateral (subcutaneous) border of the tibia and the anterior border of the fibula. The tibialis anterior muscle is separated from the extensor hallucis longus and extensor digitorum longus muscles. The anterior tibial artery runs between these muscle groups on the interosseous membrane, and then on the tibia for a short distance before it crosses the ankle into the foot underneath the superior extensor retinaculum. Graft routing options include:

- Subcutaneously, medial to lateral across the thigh, then past the knee on the lateral side.
- Subcutaneously, down the medial aspect of the thigh and across the anterior aspect of the tibia.
- Through the leg, by incising the interosseous membrane and creating a tunnel medial to lateral from the popliteal fossa to the lateral compartment.

Posterior tibial artery

The posterior tibial artery is easily exposed along its distal third by a vertical incision starting 1 cm or less posterior to the medial subcutaneous border of the tibia, extended in a 'hockey stick' fashion under the medial malleolus if necessary. The posterior tibial artery is found quite superficially situated in a groove between flexor hallucis longus and flexor digitorum longus. Bypasses are ideally suited to an *in-situ* LSV graft.

Peroneal artery

There are both medial and lateral approaches to the peroneal artery. With the lateral approach, a graft may be passed around the back of the fibula and, by lifting the flexor hallucis longus muscle back off the bone, a space can be created. More often, the lateral approach involves removing a segment of the fibula to expose the artery. Some authors describe a subperiosteal excision of the bone to allow it to be reimplanted at the end.

It is also possible to approach the peroneal artery from the medial side. This helps the harvesting and placement of the graft quite considerably. Taking an approach similar to that for the posterior tibial artery, the flexor hallucis longus is mobilised and the peroneal artery runs lateral to the tibial nerve in the groove between the fibular origin of flexor hallucis longus and tibialis posterior.

Dorsalis pedis artery

It is possible to bypass onto the dorsalis pedis artery in patients with severe crural vessel disease (a pattern of disease most commonly seen in diabetic patients). The vessel is exposed by making a vertical incision over the dorsum of the ankle and incising the extensor retinaculum lateral to the tendon of extensor hallucis longus. The proximity of the LSV is useful for *in-situ* reconstruction.

POPLITEAL ARTERY ANEURYSMS

The popliteal artery is the most common peripheral artery to be affected by aneurysmal disease, but nevertheless a popliteal aneurysm is relatively infrequent. The natural history remains largely uncertain. The principle concern is limb threat caused by either distal embolisation or acute thrombosis. All symptomatic popliteal aneurysms should be repaired, assuming that the patient is medically fit for intervention. Patients presenting as an emergency have an up to 50 per cent chance of limb loss. Most vascular surgeons will consider surgical intervention for asymptomatic popliteal aneurysms that are greater than 3 cm, although for some surgeons the threshold for intervention is higher.[18]

The aim of surgery, similar to that for aortic aneurysm, is to exclude the aneurysm from circulation and safeguard distal perfusion. A popliteal aneurysm can be approached posteriorly, through a lazy-S incision, with the patient positioned prone. This allows excellent exposure of the popliteal system in order to get above and below the aneurysm, but does limit access to the run-off vessls. It is also an unsuitable approach if the aneurysm extends above the adducter hiatus, as healthy artery will not be accessible. A short popliteal transverse skin crease incision is extended by a vertical extension up from its medial end and down from its lateral end. A vertical incision is made in the deep fascia into the fat of the popliteal fossa. The SSV may have to be ligated for access and care must be taken to protect the tibial nerves crossing the surgical field.

An alternative is a medial approach in which the above- and below-knee popliteal artery segments are approached as described above for a femoropopliteal bypasss. The LSV is also easily harvested for the reconstruction without the necessity of turning the patient during the procedure. The two separate incisions, shown in Figure 7.29, can be converted to a single incision.

A vein graft bypass is anastomosed end-to-side onto the popliteal artery, both above and below the aneurysm. Ligatures are then placed around the popliteal artery above and below the aneurysm to exclude it from the circulation (Figure 7.29).

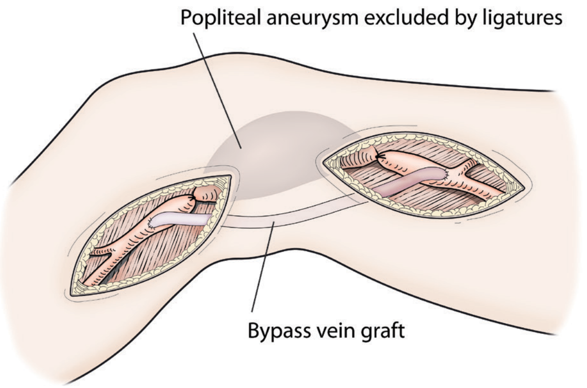

Figure 7.29 *Popliteal aneurysm. The popliteal artery has been approached from the medial aspect and ligated above and below the aneurysm. Distal perfusion is restored with a bypass graft.*

THORACIC OUTLET SYNDROME

The neurovascular bundle of the upper limb must traverse the narrow cervicoaxillary canal to enter the axilla. In addition, the vessels must pass over the first rib from their intrathoracic origin. The wide range of movement of the shoulder joint changes the shape and size of this channel, and a range of arterial, venous and neurological symptoms are reported that may be due to impingement on these structures. The majority of patients can be managed conservatively with reassurance, lifestyle changes and physiotherapy. A minority may benefit from surgical intervention.

- *Neurological symptoms* of pain, parasthesia and paresis are caused by pressure on the cords of the brachial plexus. The pressure is more often from the scalene muscles, which are attached to the first rib, rather than from the rib itself. Aberrant scalene bands to a rudimentary cervical rib are also implicated.
- *Vascular symptoms* are much less common than neurological symptoms and account for only 5 per cent of the cases. The fulcrum for the compression is the first rib. Vascular compression may give rather non-specific symptoms, but complications such as a venous thrombosis or an arterial stenosis or aneurysm can occur.

Surgical approach

Surgery for thoracic outlet syndrome is an uncommon operation in vascular surgical practice and many patients will be referred to surgeons with a special interest, both for assessment and surgery. The surgical objective is the enlargement of the space for the neurovascular bundle. This may involve removal of a cervical rib or fibrous bands or, if the skeletal anatomy is normal, partial first rib excision with release of the scalene muscle attachments. Operations for thoracic outlet syndrome can either be transaxillary or supraclavicular. The choice of approach is dependent on what structure is predominantly implicated in the compression. For example, accessory rib excision and the more extensive scalenectomy advised for upper brachial plexus compression require a supraclavicular incision. Lower brachial plexus compression and vascular compression are satisfactorily released by an excision of the middle portion of the first rib and the release of the scalene attachments to it. This is most commonly undertaken from an axillary approach. However, if arterial reconstruction, necessitated by a stenosis or aneurysm, is anticipated, a supraclavicular approach will provide superior vascular access. Details of the surgery of thoracic outlet syndrome are available in specialist vascular textbooks, but the two standard operations are summarised below.

AXILLARY APPROACH

With an axillary approach the patient is anaesthetised and stabilised in a lateral position with the arm abducted and supported. A transverse incision is made in the axilla, overlying the third rib. An axillary tunnel is developed up to the first rib on the surface of serratus anterior. Intercostal brachial nerves will usually have to be sacrificed. The dissection is then over the first rib, taking great care not to damage the subclavian artery, the subclavian vein and the brachial plexus (Figure 7.30). The vessels are gently separated from the rib and from scalenus anterior, which is then divided. The distal portion of the muscle should be excised because if it is simply

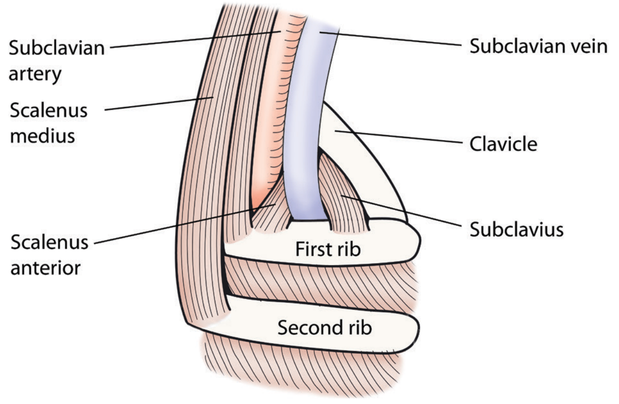

Figure 7.30 *The view of the first rib and the subclavian artery and vein from the axillary approach, with the arm abducted.*

released, adhesions from the cut end can cause recurrent symptoms. Scalenus medius and the tendon of subclavius can also be divided for additional release. The rib is then divided posteriorly behind the T1 and C8 nerves, which must be identified and protected, and finally anteriorly near the costochondral junction, while the subclavian vein is gently held out of the way.

SUPRACLAVICULAR APPROACH

With this approach an incision above the medial half of the clavicle is deepened through platysma, and the subclavian artery exposed as illustrated in Figure 6.17 (p. 100). The phrenic nerve on the surface of scalenus anterior is identified and held in a sling while the underlying muscle is separated from its attachment onto the first rib and excised. Scalenus medius is also excised. The central portion of the first rib can also be excised from a supraclavicular approach, but access is more limited and this can be technically more challenging than via the transaxillary approach. When an accessory rib is present it is usually surrounded by scalenus medius, with tendinous attachments both to it and to the first rib. The accessory rib is cleared of muscular attachments, disarticulated anteriorly and divided posteriorly, level with the transverse process. Great care is necessary to avoid damage to the T1 nerve root during this manoeuvre.

CAROTID ARTERY SURGERY

Carotid artery stenosis

An area of vascular surgery that has been examined extensively by randomised controlled trials is the management of carotid artery stenosis. Since the late 1980s, a series of trials have provided vascular surgeons with help and guidance about patient selection for carotid endarterectomy. In summary, carotid endarterectomy is indicated for symptomatic carotid territory embolic disease if the degree of stenosis is moderate to severe but the vessel remains patent. Benefits are time dependent. Risk of a further event is greatest immediately after the initial symptoms, but diminishes rapidly. Patients with asymptomatic lesions may also derive limited benefit from carotid endarterectomy. Quality control is paramount and there is significant heterogenicity throughout the published literature. A vascular surgeon must always remember that both arms of the major trials included best medical therapy in the form of antiplatelet therapy, lipid profile therapy and optimal blood pressure control and best medical therapy itself has continued to evolve since the trials.[19]

Controversies surrounding carotid endarterectomy include the use of shunts and patches and the type of anaesthesia administered. More recently, it has become clear that angioplasty and stenting of carotid lesions is both feasible and safe. Debate is now focused on which procedure, endovascular or operative, is safest and most durable.[19]

Anaesthesia

Carotid endarterectomy can be performed under regional anaesthesia, using both superficial infiltration and a deep cervical plexus block. This has the advantage of allowing selective shunting of patients based on deteriorating neurological status following the application of a clamp. The patient's motor and sensory functions can be assessed objectively, and the higher functions can be gauged by simple conversation. Despite these theoretical advantages, a recent trial has shown no difference in outcome. The decision over whether general or regional anaesthesia is used should therefore depend on the preferences of the patient, surgeon and anaesthetist.

Shunts

Shunts during carotid endarterectomy may be routine or used on a selective basis (Figure 7.31). Methods of estimating cerebral perfusion include transcranial Doppler and internal carotid artery stump pressures. However, none has given a completely reliable measure of adequate oxygenation. Although a shunt should improve cerebral perfusion during this period, shunt insertion itself carries a risk of vessel dissection, and even with a shunt in place there is an argument

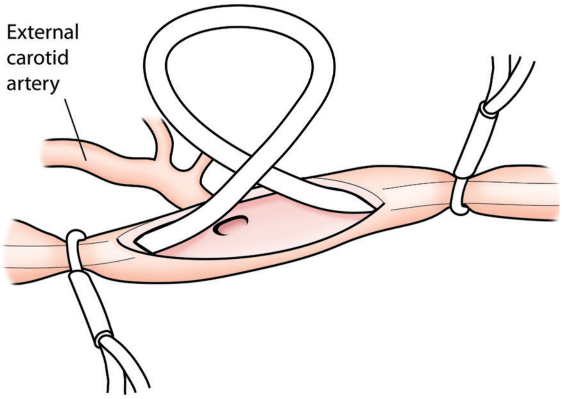

Figure 7.31 *A shunt as used in a carotid endarterectomy.*

that estimations of cerebral perfusion are still necessary to ensure that the shunt is working.

Patches

Some surgeons never patch, some patch selectively, while others always patch. There is a view that every artery will be narrowed by primary closure and that as such a patch is required. Those at the other end of the spectrum take the view that if the disease is adequately cleared and the internal carotid artery is more than 6 mm in diameter, then a primary closure is acceptable. Although the current consensus and meta-analyses support the use of patches, the practice is by no means universal. The restenosis rate is higher in women, and therefore the threshold for the use of a patch is lower. Material used for patching is also subject to discussion. Prosthetic patches have the advantage of being available 'off the shelf' and do not require harvesting, but they may become infected. Vein needs to be harvested, usually the LSV from the groin, and this is an issue if the procedure is being carried out under local anaesthesia. Vein patches can become aneurysmal and there are reports of vein patch rupture.

OPERATIVE PROCEDURE

The head is turned to the opposite side and slightly extended. Exposure of the carotid vessels can be obtained by an incision along the anterior border of sternomastoid (see Figure 10.4b p. 167). In order to avoid damage to the cervical branch of the facial nerve, the upper end of the incision should not approach nearer than 1.5 cm to the angle of the mandible. Platysma and deep fascia are divided in line with the skin incision. The sternocleidomastoid muscle is retracted laterally to reveal the internal jugular vein. This is mobilised and the common facial vein and other tributaries to it are divided. The carotid arteries lie beneath the vein. The common carotid artery is exposed first. Note the vulnerable position of the vagus nerve shown on the illustration for carotid body tumours (Figure 7.32). Not only is the vagus itself in jeopardy during dissection, but its recurrent laryngeal branch is also vulnerable. This is the cranial nerve most frequently damaged during carotid endarterectomy. The external carotid is exposed and controlled, followed by the superior thyroid artery. The internal carotid artery can then be exposed and controlled with a sling. The hypoglossal nerve can then be mobilised and, by dividing the occipital branch of the external carotid, the nerve can be pushed up out of the way. The common and internal carotid arteries require exposure adequate for shunt insertion if necessary. It is also important to expose the internal carotid to a sufficiently distal level to enable a clamp to be placed above the disease. The upper limit of the disease is often visible from the outside of the artery. The patient should now receive 3,000–5,000 IU of unfractionated heparin before the clamps are applied – internal carotid artery first, then common and external.

The common carotid artery is opened with a longitudinal arteriotomy, which is extended up into the internal carotid artery and should extend both proximal and distal to the atheromatous plaque. If a shunt is to be used, it is inserted at this stage. The endarterectomy plane is then entered. This is easiest to identify at the proximal end of the arteriotomy, and gentle outward traction on the artery wall using forceps can be helpful in providing the initial separation in the correct plane. The dissection in this plane is continued up into the internal carotid artery. The plaque normally thins distally and can be followed to its end, avoiding an intimal step in the internal carotid artery at the limit of the dissection. If,

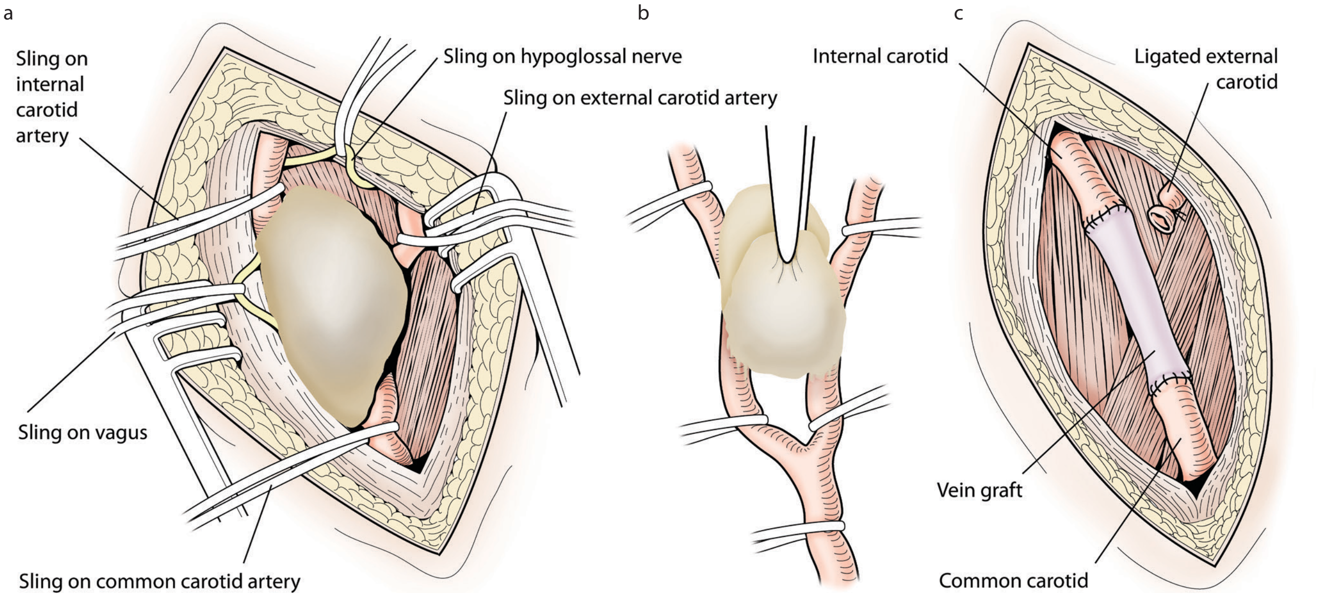
a
Sling on internal carotid artery
Sling on hypoglossal nerve
Sling on external carotid artery
Sling on vagus
Sling on common carotid artery
b
c
Internal carotid
Ligated external carotid
Vein graft
Common carotid

Figure 7.32 *Carotid body tumour. (a) Tapes have been placed around the common, internal and external carotid arteries and around the vagus and hypoglossal nerves. (b) The tumour is dissected off the vessels in the subadventitial plane. (c) When the arteries have to be excised with the tumour, the external carotid artery is ligated but a graft is interposed between the common and internal carotid arteries.*

however, an intimal step is unavoidable, it should be secured with tacking sutures to prevent dissection. Closure is either with or without a patch, as discussed above.

Carotid body tumour (paraganglionoma, chemodectoma)

The carotid body usually lies on the posterior aspect of the bifurcation of the common carotid artery. The chemodectoma that arises within it is therefore closely applied to the carotid bifurcation. Although frank malignancy and metastases are uncommon, the histological appearance does not predict either local invasion or metastatic potential. As the tumour can become progressively more difficult to separate from the carotid arteries as it enlarges, early excision is usually recommended. Clinical diagnosis depends first on clinical suspicion, and many are thought initially to represent a malignant lymph node, as they are very firm on palpation. Further investigations include CT, MRI and angiography.

OPERATIVE PROCEDURE

The approach to the carotid bifurcation is similar to that for a carotid endarterectomy and has been described above. Proximal control of the common carotid artery is the first step and, if possible, further slings are placed around the distal internal carotid and external carotid arteries. Dissection at the outer boundaries of the tumour allows the isolation, ligation and division of large thin-walled tumour vessels, and increased mobility of the tumour is achieved. Rotating the tumour forwards, top down, allows the vagus to be identified and separated from the tumour. It is then also held in a sling (Figure 7.32a).

The tumour is dissected off the carotid arteries. In most cases there is a subadventitial plane of cleavage that can be followed (Figure 7.32b). The tumour blood supply is often predominantly from the external carotid artery. Use of an Harmonic® scalpel is a safe and efficient way to proceed down the plane between the external carotid and the tumour. The arterial wall is left otherwise intact, and aneurysmal dilation is not a complication. When the tumour is circumferential it may have to be transected until the correct plane is reached. However, in some tumours this subadventitial plane cannot be followed and a segment of the carotid arteries must be resected with the tumour. A carotid reconstruction is then performed with a vein graft anastomosed to the common carotid below the tumour and to the internal carotid above it. The external carotid is simply ligated and divided (Figure 7.32c). During the resection and reconstruction a temporary shunt is usually established to maintain inflow into the internal carotid artery and safeguard cerebral perfusion.

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8

CARDIOTHORACIC SURGERY FOR THE GENERAL SURGEON

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INTRODUCTION

General surgeons need to know how to open the chest in an emergency. Those working in hospitals without cardiothoracic units may have to perform anything from a simple chest drain insertion to an emergency 'clamshell' thoracotomy in a patient who is too severely injured to allow stabilisation for transfer to a cardiothoracic unit. In the UK, most of the elective intrathoracic vascular and oesophageal surgery is now concentrated into tertiary referral centres. However, a vascular or upper gastrointestinal surgeon operating in the abdomen or neck may encounter unexpected pathology or an intraoperative complication that necessitates access to the thoracic aorta or oesophagus when this has not been anticipated preoperatively.

In resource-limited situations in the developing world, thoracic pathology represents an enormous burden of disease, which consists predominantly of inflammatory pleuropulmonary disease and trauma. Surgeons who are unable to transfer either elective or emergency cardiothoracic cases are unfortunately unlikely to have the necessary anaesthetic or intensive care facilities available to justify embarking on major intrathoracic surgical procedures. However, simple timely interventions can prevent the development of major thoracic pathology. An excellent example is the patient with a haemothorax from a stab wound. Simple insertion of a chest drain to evacuate the haemothorax and re-expand the lung is needed. However, when inadequately managed, the haemothorax becomes organised, the pleural space becomes infected and a chronic empyema with permanent entrapment and destruction of the underlying lung ensues.

The success of all but the most minor cardiothoracic surgery is linked to the perioperative anaesthetic support available. The physiological changes associated with opening the chest require skilled anaesthesia. Once a hemithorax is open in a patient who is breathing spontaneously, the lung on that side collapses, while adequate spontaneous ventilation of the remaining lung is also severely compromised. A cuffed endotracheal tube and positive-pressure ventilation overcome these mechanical problems, but the lung in the opened hemithorax will inflate and obscure the operative field. The double-lumen endotracheal tube not only allows separation of the lungs for ventilatory purposes but diminishes the risk of spillage of endobronchial secretions and blood from the operated lung to the airway of the contralateral dependent lung (Figure 8.1). Unfortunately, either the tube or the anaesthetic skills to insert it may not be available. Single lung ventilation is possible with a single-lumen tube but it has to be advanced into the main bronchus of the lung to be ventilated. This technique is not as efficient in

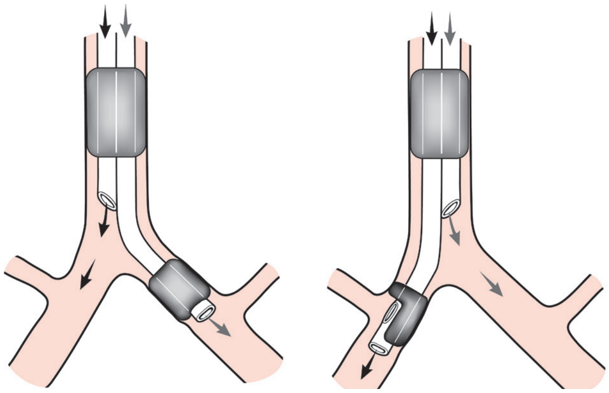


Figure 8.1 *Double-lumen endotracheal tubes serve a dual role. In addition to allowing separate ventilation of either lung, the double cuffs protect the good lung from overspill across the carina from the other lung.*

permitting deflation of the lung on the side of the operation, does not provide such secure protection of the dependent airway and the option to ventilate both lungs intermittently if oxygen saturation falls is lost. Endobronchial blockers such as Fogarty balloons are fiddly, difficult to maintain in position and, in the hands of the uninitiated, usually prove ineffective in maintaining lung separation. If a single-lumen tube positioned in the trachea is the only option, lung retraction by the assistant will provide some visibility of the surgical target. It usually requires a reduction in the ventilatory tidal volume, which is compensated for by increasing the respiratory rate to maintain adequate ventilation.

If the chambers of the heart, ascending aorta or pulmonary trunk are injured or have to be opened, circulatory arrest will greatly diminish the blood loss. Snares can be placed around the superior vena cava (SVC) and inferior vena cava (IVC) to occlude inflow and produce circulatory arrest. Unfortunately, unless a surgeon is familiar with operating in the chest, placing a snare around the SVC in the face of a crisis may be an insurmountable obstacle. A further challenge in an emergency is that whereas a circulatory arrest can be safe for a minute or so in the well-perfused patient with a high oxygen saturation, it can be the last straw for a hypovolaemic and desaturated patient. Without specialised support and the backup of cardiopulmonary bypass, manoeuvres to induce circulatory arrest following cardiac injury are almost universally fatal. In addition, surgery on the heart and great vessels may require the heart to be kept still for fine work to be undertaken safely. Specialised techniques, which include hypothermia to extend the time of safe circulatory arrest and arrest of the heart, in addition to extracorporeal circuits that maintain perfusion during the operation, have greatly expanded the scope of cardiac surgery. However, as they are not options for the general surgeon, they are not described further.

In elective and emergency surgery on the intrathoracic aorta, even if the proximal clamp can be placed so that cerebral perfusion is maintained, the spinal cord and kidneys will be ischaemic. The haemodynamic effects of occluding the major part of the cardiac outflow in a beating heart is another relevant consideration. Limited shunts to maintain perfusion to vital organs may occasionally have a place but are seldom a practical solution in an emergency outside of a cardiothoracic unit.

General surgeons are therefore restricted in what they can realistically offer when they are unable to stabilise a patient for transfer to a cardiothoracic unit or when working in an environment where there are no transfer options.

SURGERY OF THE PLEURAL SPACE AND CHEST WALL

Intrapleural collections of fluid, air, pus or blood displace the lung and reduce its functional capacity, leading to collapse, shunting and hypoxia. An inadequately drained haemothorax will organise and an infected pleural collection will progress to a chronic empyema, with permament damage to the underlying lung. Drainage is therefore important and although sterility is essential, both aspiration and chest drain insertion can be done at the bedside with local anaesthetic infiltrated down to the parietal pleura. The needle or drain should be introduced close to the superior border of a rib to avoid damage to the intercostal neurovascular bundle (Figure 8.2).

ASPIRATION

Aspiration is suitable for drainage of a serous pleural effusion. It does not provide adequate drainage for blood or thick pus. Only 10–20 ml is needed for cytological or bacteriological analysis, but a larger effusion is usually aspirated completely to allow lung re-expansion and a two-way tap will be required to prevent air entry. With the patient sitting, an appropriate posterolateral site is chosen. It should be remembered that the hemidiaphragm may be elevated and that in the presence of inflammation, the two layers of pleura in the costodiaphragmatic recess are often adherent. If too low a site is chosen, it is easy to enter the abdomen and damage the liver or spleen (Figure 8.3).

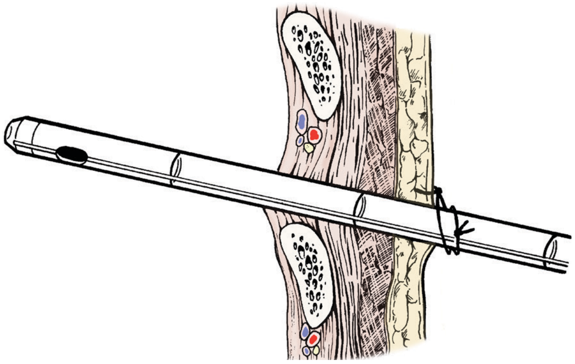


Figure 8.2 *The intercostal neurovascular bundle is partially overhung by the rib above. Damage should not occur during the insertion of an aspiration needle or intercostal drain placed immediately above a rib.*

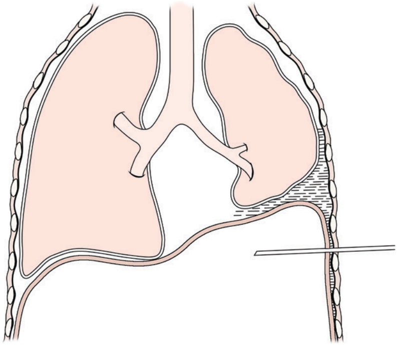


Figure 8.3 *A basal pleural effusion is often associated with an elevated hemidiaphragm and fused peritoneum in the costodiaphragmatic recess. If too low a site is chosen for aspiration, the abdomen is entered inadvertently.*

Air is easily aspirated through a needle, and aspiration is currently recommended by the British Thoracic Society for a moderate pneumothorax. In a small simple pneumothorax, observation alone may be sufficient, while in a more major pneumothorax a chest drain is more effective and safer, particularly if the patient is symptomatic or has underlying lung disease.[1] Release of a tension pneumothorax with a large-bore needle can, however, be a temporary life-saving manoeuvre, as the displaced mediastinum is both obstructing venous return and reducing the functional capacity of the contralateral lung. In an emergency, although it is recommended that the needle is introduced through the second intercostal space in the mid-clavicular line, the proximity of the superior mediastinal vessels must be remembered, and the alternative site in the 'safe triangle' (see below) has advantages. Air escapes under pressure until the mediastinum has returned to the midline; a tension pneumothorax has thus been converted to a simple pneumothorax and a chest drain is then inserted with the patient no longer in severe respiratory distress.

CHEST DRAIN INSERTION

Insertion of a chest drain is the standard treatment for any infected pleural effusion, for most significant pneumothoraces and for a haemothorax. A chest drain is also usually indicated at the end of an operation in which the pleural space has been entered to drain any postoperative collection of blood or leakage of air. An intercostal drain may be required with some urgency following thoracic trauma. Positive-pressure ventilation can also convert a small undetected simple pneumothorax into a tension pneumothorax. This should be remembered in patients with multiple injuries who require a general anaesthetic, or ventilation, as part of their general management. Prophylactic chest drain insertion before induction of anaesthesia should therefore always be considered, even after apparently insignificant chest trauma. In these circumstances a chest drain is inserted in a supine patient. In an elective setting a chest drain can be inserted with the patient sitting, with the arm held across to the opposite shoulder.

The recommended 'safe triangle' for insertion is bounded by the mid-axillary line posteriorly, the lateral border of pectoralis superiorly and inferiorly by a line projected from the 5th intercostal space anteriorly. A small incision is made through the skin and intercostal muscles. The parietal pleura is either incised or gently penetrated with the artery forceps. A finger is inserted into the wound track to confirm entry into the pleural space. The chest drain can then be safely introduced and angled up towards the apex for a pneumothorax or down to the lung base for a haemothorax.

Trochar techniques are inherently dangerous. The sudden loss of resistance as the parietal pleura is entered allows the momentum to carry the trochar point into the substance of the underlying lung and, potentially, even into hilar structures. Increasingly, the use of percutaneous 'Seldinger' (over the wire) chest drains are advocated by chest physicians and interventional radiologists, typically in the elective setting. They are smaller (12Fr or less) and should be inserted using ultrasound guidance. As such, they are often placed outside the 'safe triangle', particularly when dealing with loculated pleural effusions.

A chest drain must be securely held in place with a suture, which will also prevent any air leakage around the tube. A further untied suture can be inserted at this stage and will be tied as the drain is removed to prevent air entry through the track (Figure 8.4). Underwater drainage is established immediately after the drain is in the pleural cavity (Figure 8.5). Air is expelled with each breath and bubbles through the water. No air can be drawn back into the pleural space, and there is no danger of the fluid in the bottle being drawn back

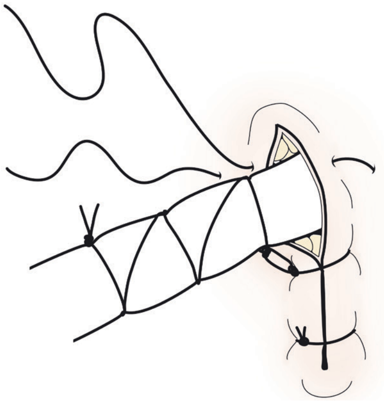


Figure 8.4 *The chest drain is securely held in place by a skin suture, which is also snugging the skin around the drain. The suture can be cut in such a way that it releases the drain but still holds the skin in apposition. An additional untied mattress suture is in position. This will be tied as the drain is withdrawn to prevent air entry into the pleura along the drain track. Purse-string sutures are no longer recommended.*

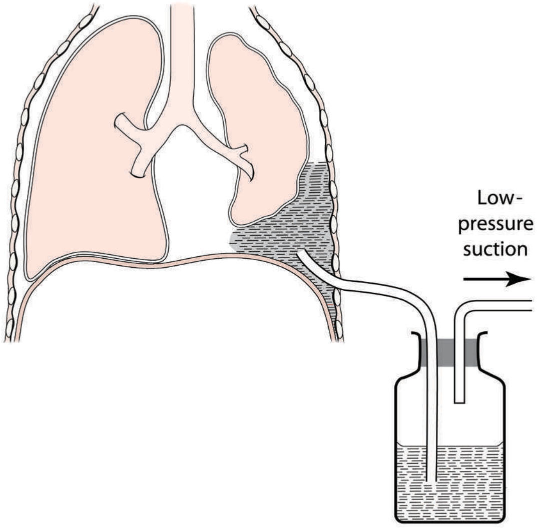


Figure 8.5 *Underwater seal drainage, with or without suction, is a simple well-tried system of chest drainage.*

if the bottle remains below chest level. Low-pressure suction can be added for more efficient drainage, but it is important to remember that a negative suction apparatus that fails is in essence the same as a clamped chest drain, with the danger of a tension pneumothorax in the presence of a continuing air leak.

A chest drain should not be removed until it has achieved the purpose for which it was inserted. The lung must be fully inflated, no air should have bubbled for at least 24 hours and any fluid still draining must be non-purulent. Drain removal is performed under the protection of a sustained Valsalva manoeuvre to prevent the entrance of air into the chest before the skin suture is tied. A post-removal chest X-ray is then taken to exclude this.

Surgical suture of an air leak is occasionally required when chest drain therapy fails to achieve re-expansion of the lung and air continues to bubble. Thoracic surgeons differentiate between air leaks at alveolar level in the periphery of the lung and bronchopleural fistulae, which originate in the more proximal airway. Peripheral air leaks generally close spontaneously within a few days provided the lung is fully reinflated and the visceral and parietal pleura are in contact. Occasionally, associated surgical emphysema is extensive, even extending into the face or scrotum. Incisions in the skin to allow the air to escape are not indicated. Only drainage of the pleural space is required, as with re-expansion of the lung the air leak is sealed against the parietal pleura.

A haemothorax that continues to accumulate may require a thoracotomy, as discussed later in this chapter.

A complication of pneumonia in which the parapneumonic effusion becomes infected is the commonest cause of a pleural infection. Treatment is with antibiotics and drainage of the pus from the pleural space by chest drain. However, this is often insufficient, especially if the pus is thick and presentation late. The lung fails to re-expand to fill the empyema space and further surgical intervention is required to prevent the development of a chronic empyema.

Surgery for empyema

An important principle in the management of any pleural space infection is that early surgical intervention yields superior results over continued inadequate drainage by tube thoracostomy. Early referral to a thoracic unit for debridement or decortication is therefore important. Chronic pyogenic or tuberculous empyemas are relatively frequent in areas where health resources are limited. When no cardiothoracic referral is possible, a general surgeon should consider an open drainage procedure.

DEBRIDEMENT AND DECORTICATION

Intervention can be either with a video-assisted thoracoscopic (VATS) approach or an open operation. The choice is influenced by the degree of lung entrapment, reflecting the thickness of the pleural 'cortex', which also influences whether debridement or decortication is more appropriate. Vigorous debridement alone of the pleural cavity may allow re-expansion of the lung, but older more chronic empyemas often require decortication, which involves the excision of the thickened visceral and parietal pleura that form the walls of the empyema. The lung may still be reluctant to expand to fill the space and may now additionally have air leaks from where the visceral pleura was stripped. Decortication is not an operation suitable for a generalist.

OPEN DRAINAGE

Open drainage is safe for *chronic* empyemas with a thick cortex. The lung is adherent to the parietal pleura and will not collapse when a limited thoracotomy into the abscess alone is performed. Intrapulmonary pus can also be drained in the same manner if the inflammation has extended out to the pleura with resultant pleural adhesions preventing lung collapse.

Open drainage with or without rib resection can be undertaken under general or local anaesthesia. The excision of 3–4 cm of rib allows greater access into the empyema for debridement (Figure 8.6). After all the pus and necrotic material has been washed out, a drain is secured into the depths of the cavity.

Thoracostomy is a more permanent skin-lined, 3–4-cm fenestration of the pleural space, employed to drain a chronic empyema when other solutions to fill and close the pleural space are not possible. An H-shaped incision produces two horizontal skin flaps. A segment of around 6 cm is then removed from two adjacent ribs, along with their periosteum and the intervening intercostal muscles, neurovascular bundle and parietal pleura, to create a chest wall defect. The skin flaps are then sutured to the parietal pleura.

SURGICAL ACCESS TO THE CHEST

Minimal-access and endoscopic intrathoracic techniques are valuable for both diagnostic and interventional purposes. Access for open intrathoracic surgery may be anteriorly through the sternum, laterally between the ribs or from below through the diaphragm. There is also limited access from the neck. The choice of incision is important, as a poorly positioned incision makes a relatively simple intrathoracic procedure difficult.

Bronchoscopy

Although bronchoscopy is currently almost exclusively performed under local anaesthesia with flexible instruments, a rigid scope might still be the only available option for a general surgeon in difficult circumstances. A general anaesthetic will be required with the anaesthetist assisting with airway management and ventilation during the procedure.

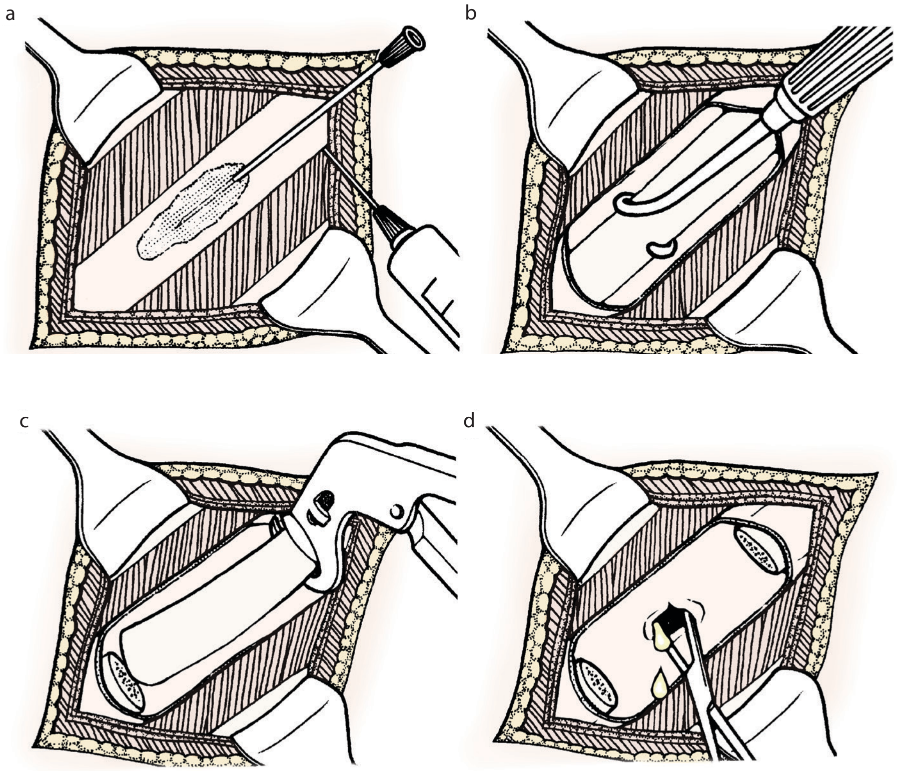


Figure 8.6 *Drainage with rib resection. (a) When performed under local anaesthesia, lidocaine must be injected under the sensitive periosteum. (b) The periosteum is incised longitudinally and elevated from the rib. The deep surface can be stripped of periosteum with a curved periosteal elevator. (c) A section of rib is resected. (d) The posterior periosteum and pleura are incised.*

Mediastinoscopy

A mediastinoscope is introduced into the anterior superior mediastinum through a small transverse incision above the suprasternal notch. Mediastinoscopy is of particular value in the assessment of a superior mediastinal mass and in the pre-treatment lymph node staging of a bronchial malignancy. Major vessel injury is a significant risk and if a general surgeon requires histology of upper mediastinal nodes, a small second interspace incision (a mediastinotomy) is a safer alternative.

Video-assisted thoracoscopic surgery

This approach uses a variable number of port incisions depending on the procedure (Figure 8.7). VATS surgery has revolutionised thoracic surgical practice because by avoiding large muscle-cutting incisions and especially rib-spreading, it significantly improves postoperative recovery. Increasingly, in specialised thoracic centres the majority of procedures are performed through such minimal-access approaches, although a mini-thoracotomy through the anterior aspect of an intercostal space will be required for specimen delivery when a resection has been undertaken.

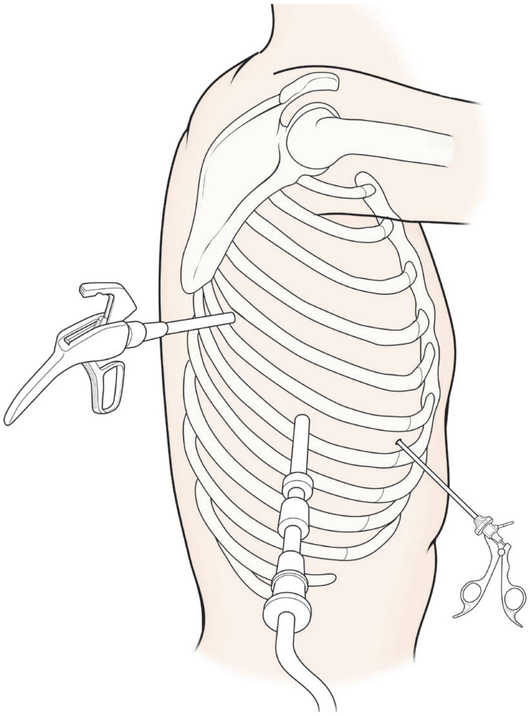


Figure 8.7 *Thoracoscopic surgery has an increasing role in intrathoracic pathology.*

Median sternotomy

This is the incision that is performed most frequently for elective cardiac surgery and provides excellent access to the heart and anterior mediastinum. It may also be the most appropriate incision in an emergency when damage to the heart or to the great vessels of the superior mediastinum is suspected. The incision can be extended up into the neck along the anterior border of sternocleidomastoid for injuries of the carotid root, or laterally above the clavicle for access to an injury to the subclavian root (see also Chapters 6 and 10).

A vertical midline skin incision is made from the suprasternal notch to the xiphisternum and deepened down to the periosteum of the sternum. The periostium is scored down the midline with the diathermy blade to reduce the bleeding when the manubrium and sternum are divided along this line using an electric oscillating saw designed specifically for this purpose. If this is not available, a longitudinal substernal tunnel is made close to bone with long forceps, and a Gigli saw is passed underneath the sternum with the aid of a long artery forceps (see Chapter 5). There is danger of injury to the underlying heart and it is also easy to breach the right pleura. Opening the sternum in repeat surgery is hazardous as the heart may be adherent to the sternum. It should only be attempted with an oscillating saw, which cuts through the outer table first, then the inner table, without jeopardising adherent structures beneath the sternum. Bleeding from the sternal marrow is reduced by the application of bone wax.

The sternum should be separated from underlying structures before attempts are made to separate the edges widely with a self-retaining retractor. The pleural sacs are swept off the pericardium, and no entry into either pleural space is required. The thymus, lying on the pericardium in the superior mediastinum, is divided in the plane between the lobes, avoiding the innominate vein superiorly. The pericardium is then incised vertically.

After surgery within the pericardium, drains should be left both inside the pericardium and in the anterior mediastinum. The two halves of the sternum are then drawn together. Stainless steel wire sutures can either be introduced through the sternal bone with a heavy needle, or they can be placed further laterally through the intercostal fascia at the lateral sternal edge. The latter are easier to insert, but there is a danger of injury to the internal mammary artery. It is important that the sides of the sternum are very firmly pulled together by the sternal wires, which are then twisted with pliers to maintain a rigid approximation of the two halves of the sternum. Poor closure at this point will result in chronic pain, non-union and dehiscence.

Posterolateral thoracotomy

This is the standard approach for elective surgery of the lung. A right thoracotomy affords excellent access to the thoracic oesophagus and a left lateral thoracotomy access to the descending thoracic aorta. Access to the hilum of a lung and the mediastinal structures is good, but only on the respective side. In elective surgery, the level of the incision may be dependent on the underlying pathology, but in an emergency the 5th intercostal space is the most satisfactory. Patients are positioned on their side with pelvic support to secure stability. A bolster under the lower side of the chest is helpful, as the lateral flexion separates the ribs. The upper arm is elevated and adducted away from the chest to lie over the face (Figure 8.8). Some teams use an arm support to hold the arm in position, although others believe that this increases the likelihood of postoperative shoulder pain.

The incision is made through the skin and latissimus dorsi in the same line (Figure 8.9), and should be two finger breadths below the tip of the scapula. Posteriorly, the skin incision may turn up to divide the angle between the spine and the medial edge of the scapula. Anteriorly, it extends into the submammary fold. It is then deepened through the latissimus dorsi, the fibres of which are at about 90 degrees to the incision. The plane deep to latissimus dorsi is then developed upwards, under the scapula. The ribs and intercostal muscles are now exposed so that it is possible to count the ribs and plan the appropriate level for the thoracotomy. The edge of the 2nd rib is the highest rib that can be felt under the scapula, and the flat surface of the 3rd rib is then palpable below it. Having identified the chosen space for the thoracotomy, the lower border of serratus anterior is freed from the underlying fascial and fatty plane by coagulation diathermy and divided as low as is practical to preserve innervation. If more space is needed, the trapezius can be divided.

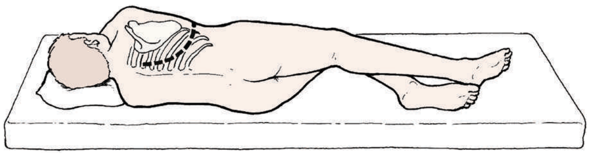


Figure 8.8 *In the full lateral position the patient is unstable and must be securely supported and strapped. The uppermost arm also requires careful positioning and support.*

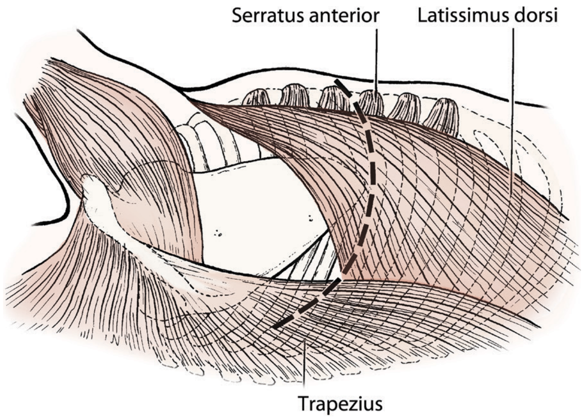


Figure 8.9 *Landmarks for a lateral thoracotomy.*

Entry into the chest may then be either through the intercostal muscles, directly along the upper border of the rib, or through the periosteum on the upper border of the rib. (Figure 8.10a). The anterior surface of the rib is scored with the diathermy blade. A periosteal elevator is inserted under the edge of the periosteum at the posterior end of the rib and then drawn along the course of the rib to the anterior end. Stripping should be from back to front, as the fibres of the intercostal muscles then keep the dissection on the upper border of the rib (Figure 8.6). The pleural cavity is then entered through the posterior periosteum. Care must be taken to avoid injury to the underlying lung, and a moment's apnoea from the anaesthetist can be helpful. Rib resection is not necessary, though 'notching' the rib (cutting a small segment of rib posteriorly) can help avoid uncontrolled fractures during rib-spreading. Alternatively, rib fractures can also be avoided by division of the costotransverse ligament posteriorly, which allows greater mobility of the superior rib during spreading.

Once the pleura is incised, the anaesthetist can allow the lung to collapse out of the operating field if a double-lumen tube is in place. The ribs are spread carefully using a self-retaining retractor, but overspreading should be avoided as this can also damage the intercostal neurovascular bundle, with resultant postoperative neuralgia.

One or two chest drains are commonly placed in the pleural cavity at the end of surgery before closure, and are brought out through separate stab incisions. Rib apposition can be held by four pericostal sutures spaced along the incision (Figure 8.10b), followed by a continuous suture approximating the upper leaf of the divided periosteum to the fascia over the intercostal muscle in the space below (Figure 8.10c). The chest wall muscles are then repaired with absorbable sutures.

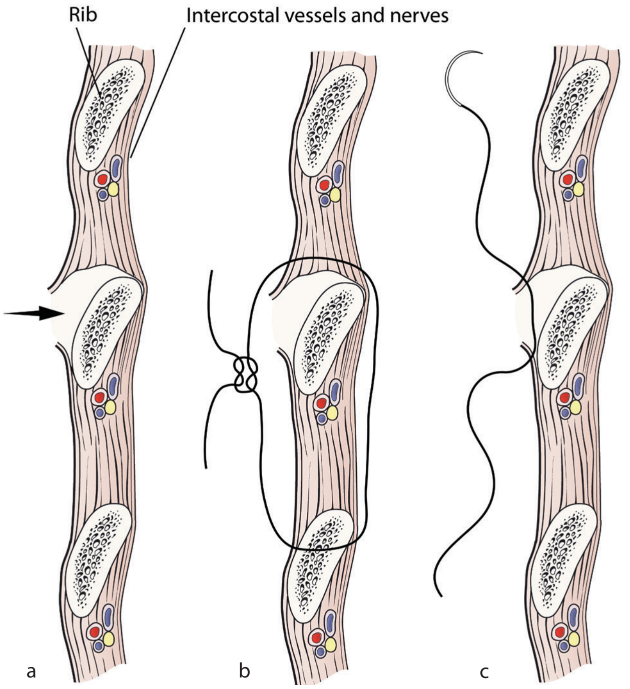


Figure 8.10 *Lateral thoracotomy. (a) The periosteum has been incised along a rib. The upper leaf of periosteum is elevated from the lateral surface and upper border of the rib to expose the posterior periosteum. The posterior periosteum and parietal pleura are then incised to enter the chest. (b) A pericostal suture passed over a rib will not damage the intercostal neurovascular bundle. Below a rib it can cause damage and it is preferable to pass it through the rib instead. (c) A continuous suture approximating the divided periosteum to the fascia overlying the intercostal muscles of the space below completes the closure of the chest wall.*

Transaxillary lateral thoracotomy

This is a limited lateral thoracotomy, performed through the medial wall of the axilla, which affords restricted access to the apex of the lung. It was a standard approach for a thoracic sympathectomy but it has now generally been superseded by a thoracoscopic technique.

Anterolateral thoracotomy and clamshell thoracotomy

A left anterolateral thoracotomy is often the incision of choice for emergency access to the heart and may be the prelude to a bilateral anterior thoracotomy or 'clamshell'. Access to the posterolateral aspect of the left ventricle is superior to that obtained with a median sternotomy but, more importantly, it is a faster and safer approach, especially in the absence of the necessary saws. The patient is laid obliquely supine with the ipsilateral hip and shoulder raised and the arm abducted. A left 5th space anterolateral thoracotomy can be extended by a transverse or oblique division of the sternal body to a 5th or 4th interspace right anterolateral thoracotomy if greater access is required. In this *clamshell thoracotomy* both internal mammary arteries must be ligated and divided. A clamshell thoracotomy is the preferred approach to the heart and chest cavity in an extreme emergency.[2] For blunt chest trauma the incision is started as a left anterolateral thoracotomy to gain rapid access to the perciardum and heart and is then extended as required. For penetrating chest trauma the side of the initial incision is guided by the site of injury.

Thoracoabdominal incisions

These incisions are described in Chapter 13. They are now generally avoided as both postoperative pain and respiratory complications are common. A left thoracoabdominal incision was routinely used for cancers of the gastric cardia and lower oesophagus. The alternative access for this surgery is discussed in Chapters 17 and 18. A right thoracoabdominal incision was used for liver surgery, but the alternative subcostal incision provides good access to the mobilised liver, with less morbidity.

Transhiatal access

Transhiatal access to the posterior mediastinum has the advantage that it does not necessitate entry into either pleural space. In addition, there is less postoperative respiratory compromise when compared with a thoracotomy. Transhiatal access to the oesophagus is now the routine approach for much of the laparoscopic surgery of oesophageal reflux and hiatus hernia. In surgery for cancer of the cardia and distal oesophagus, a similar approach for dissection around the distal oesophagus can be combined with an open laparotomy (see Chapters 17 and 18). In the presence of a hiatus hernia, access through the stretched hiatus may be ample. A normal hiatus can be enlarged, if necessary, by a diaphragmatic incision, which is later closed.

Cervical access

Access into the superior mediastinum from incisions in the neck is limited. It is, however, a suitable approach to a proximal tracheal injury and is also usually sufficient to free a retrosternal goitre (see Chapter 10). Cervical access is employed by some surgeons as an alternative to sternotomy for thymectomy in myasthenia gravis. The cervical approaches to the roots of the vessels arising from the aortic arch are described in Chapters 6 and 10.

SURGERY FOR CHEST TRAUMA

The first priority in thoracic trauma is to re-establish the mechanical requirements for adequate circulation and blood–gas exchange. As in all trauma, volume resuscitation and the clearance of any airway obstruction is paramount, but in chest trauma assessment of the need for pleural drainage and its establishment, if required, are as urgent. Myocardial contusion and tamponade must be borne in mind when a patient does not respond to this initial management, as well as the altered response to resuscitation when the trauma is compounded by alcohol intoxication or hypothermia.

Only in a minority of cases is a thoracotomy necessary. Penetrating injuries, which are usually stab wounds, can almost always be managed by pleural drainage and blood replacement. Blunt injuries, with multiple rib fractures and lung contusion, more frequently require the addition of mechanical ventilation. Most general surgeons would hope to be able to transfer patients requiring an emergency thoracotomy to a cardiothoracic unit. However, except in regional centres, general surgeons will have to manage the initial problems themselves to make patients fit for transfer. The patients frequently have other major neurological, abdominal or limb injuries.

Occasionally, the general surgeon will be faced with a patient who cannot be stabilised by mechanical ventilation, drainage of the pleural space and replacement of circulating volume. Thus, transfer becomes impossible and the only chance of survival is with an emergency thoracotomy.[3] General surgeons may have skilled anaesthetic and intensive care facilities, but no access to cardiopulmonary bypass, and will be operating in difficult conditions in an area in which they are probably unfamiliar.

Infrequently, this emergency surgery must be performed on an unconscious, unanaesthetised dying patient in the accident department in a desperate attempt to control torrential haemorrhage. An immediate 'emergency room' thoracotomy forms part of the resuscitation of a patient *in extremis* following thoracic trauma. A cardiac laceration is the commonest remedial injury. In major trauma centres serving areas with a high level of civilian violence, these immediate thoracotomies have resulted in success in around 10 per cent of those with penetrating thoracic injuries.[4,5] Outside these centres, the results from emergency room thoracotomies will be more disappointing, but nothing is lost in the attempt and an occasional life will be saved. If death is imminent, a low likelihood of benefit is tolerable.

Fortunately, however, it is very rare for the general surgeon to be be placed in this situation. Management instead revolves around the need for blood replacement, pleural drainage and artificial ventilation, with the possible transfer of a stable patient if this seems appropriate.

Mechanical considerations

Inadequate gas exchange in the immediate aftermath of chest trauma is more often due to mechanical factors than to extensive pulmonary damage.

PLEURAL SPACE EXPANSION

Air or blood within the pleural space, which is reducing respiratory capacity, must be drained by the insertion of a chest drain. In a severe case, the physical signs of major respiratory embarrassment, tracheal deviation, absent breath sounds and a dull or hyperresonant hemithorax may necessitate action even before a confirmatory chest X-ray has been taken.

CHEST WALL STABILISATION

The mechanical integrity of the chest wall is threatened by multiple fractured ribs if, on inspiration, an area between fractures is drawn in as a flail segment. More commonly, however, it is simply the pain from multiple unstabilised fractures inhibiting good respiratory effort that is the problem. Stabilisation of the chest wall can be achieved either by endotracheal intubation and artificial ventilation or by open reduction and fixation. Local anaesthetic (bupivacaine) intercostal blocks and thoracic epidurals can be of great value in reducing pain, increasing voluntary respiratory effort and thereby reducing secondary infection in poorly aerated lung bases. Not only are these techniques of particular value when ventilatory support is not an option, but they are routinely used and evaluated in attempts to reduce the duration of artificial ventilation.[6] Simple strapping to support a rib fracture is often condemned for its restrictive respiratory effect. However, the pain relief afforded allows fuller diaphragmatic movement, which may more than compensate. Open reduction and fixation is seldom indicated but can be considered when the chest has already been opened, when there is a severe deformity from the injury or when other options to control severe pain or a flail segment have failed.

Unfortunately, much of the problem of deteriorating gas exchange in the days after chest trauma is not explained on the basis of mechanical compromise or secondary infection. The lungs themselves were injured, and the deteriorating function is more often related to lung contusion.

OPEN CHEST WOUND

Open chest wounds should be closed after insertion of a chest drain. Even if closure is not immediately possible due to tissue loss, the situation is manageable with positive-pressure ventilation. In the field, an airproof dressing to restore the mechanical integrity of the chest wall, combined with a chest drain, may be life saving if the patient is still breathing spontaneously.

DIAPHRAGMATIC LACERATION AND RUPTURE

The possibility of a diaphragmatic laceration should be considered in all penetrating injuries to the chest or abdomen.[7] The incidence of diaphragmatic injury in association with stab injuries to the lower chest may be over 10 per cent. Small lacerations may be symptomless initially and the diagnosis is easily missed, only to present with late complications of herniation of an abdominal viscus through the defect. Positive-pressure ventilation may keep abdominal contents in the abdomen, but they then herniate through the defect when the patient breathes spontaneously with negative pressure. Repeat X-rays during the initial hospital admission may therefore demonstrate a tear that was not apparent on an earlier X-ray. This may avoid some of the late presentations, years after an injury, when a gradual increase in the size of the defect leads to increased herniation of abdominal organs.

Blunt trauma that compresses the chest or abdomen can also rupture the diaphragm, which most commonly tears posteriorly on the left. A major rupture of the left hemidiaphragm can seriously impair respiratory function as the abdominal contents herniate into the chest. The situation is worsened by gaseous distension of the stomach; nasogastric aspiration is worth instituting before transfer to theatre, although it will not always deflate the herniated stomach. A right-sided diaphragmatic rupture is less common, more difficult to diagnose and seldom presents with early acute mechanical difficulties with ventilation. Diaphragmatic injury may be isolated, but is often associated with damage to the liver, spleen or left colonic flexure. A ruptured spleen lying within the chest and causing a haemothorax can cause diagnostic confusion.

In an acute presentation the diaphragm is most often repaired from below at laparotomy. Herniated organs must be gently extracted from the chest, and it may be necessary to enlarge the diaphragmatic defect to do this. This should be done with consideration of the orientation of the branches of the phrenic nerve in order to minimise denervation of the diaphragm. The edges of the laceration are then securely approximated with strong interrupted sutures. After each suture is tied it can be used to lift the edges of the diaphragm and thus make placement of the next suture easier. This manoeuvre will also reduce the potential for damage to the underlying heart or lung.

If diaphragmatic injury is suspected, and there is no other indication for a laparotomy, a laparoscopy can confirm or exclude it. However, at diagnostic laparoscopy both the surgeon and the anaesthetist must be aware of the potential risk of a tension pneumothorax due to the communication between the thoracic and abdominal cavities. If this occurs, the gas of the pneumoperitoneum is released. If this does not produce an instant improvement, then needle chest decompression followed by chest drain insertion is required. Thoracoscopy is a useful diagnostic alternative, especially as in experienced hands a repair can also be carried out using this minimally-invasive approach.

Diaphragmatic injuries that present some months or years later will require a careful dissection to free the abdominal viscera from within the chest, in order to return them to the abdominal cavity before the diaphragmatic defect is sutured. For late injuries a thoracic approach is thus often preferred and, as it may no longer be possible to bring the edges together, a mesh must then be used to bridge the defect.

Surgery for intrathoracic bleeding

The indication for surgery may be the magnitude of the bleeding, usually through a pleural drain, but occasionally directly to the exterior. Other indications include cardiac tamponade and evidence of mediastinal bleeding, suggesting a significant major vessel injury.

BLEEDING INTO THE PLEURAL SPACE

An initial drainage from the pleural space of a haemothorax of more than 1,500 ml or, once the chest drain is in place, a continuing blood loss of more than 200 ml per hour suggests a source of bleeding that is unlikely to stop spontaneously and will require surgery. The risks and benefits of transfer to a cardiothoracic centre have to be individually weighed.

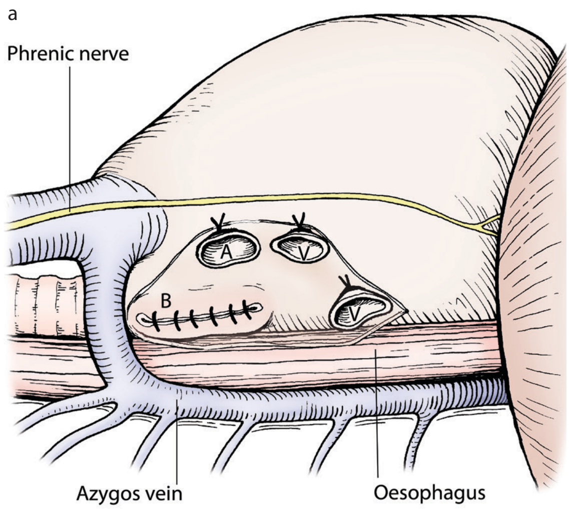
The rate of haemorrhage, the distance for transfer, the local expertise and the likely source of haemorrhage may all be factors in the decision. The spectrum of injury after penetrating trauma differs from that encountered after blunt trauma. In the depth of a stab wound the surgeon will usually encounter an injury similar to a surgical incision, and this can be sutured. In blunt trauma, general surgeons are less likely to find injuries that they can easily control or repair. The contused injury will not resemble a surgical incision and it is seldom amenable to a simple sutured repair. For example, a patient with a stab injury to the lateral chest is probably bleeding from a severed intercostal artery or a simple lung laceration. A posterolateral thoracotomy on the side of the injury, to secure an intercostal vessel or suture a lung laceration, is not an unduly difficult or hazardous procedure, but the confidence of general surgeons to open a patient's chest in an emergency will vary. In contrast, a patient who has a haemothorax following a blunt deceleration force, or a bullet wound in the superior mediastinum, is more likely to have complex injuries to vital structures that may require bypass facilities and surgeons with experience in the field. More may be lost in a stable patient by a thoracotomy without these essentials than by the delay incurred in transfer. The value of telephone advice from a cardiothoracic surgeon must be remembered whenever a general surgeon is unsure whether to transfer a patient or to proceed with a thoracotomy. An expert can sometimes talk another surgeon through an operation or may offer to come and help; alternatively, transfer may be recommended with the specialist team already alerted and the emergency operating theatre prepared.

Once it has been decided to proceed, the incision must be chosen. A posterolateral thoracotomy on the side of the haemothorax was the traditional teaching. However, it must be remembered that, particularly in penetrating trauma, an injury to the heart or mediastinal vessels may present with early major bleeding into the pleural space. If a cardiac injury is suspected, an anterolateral thoracotomy to the side of the injury, or to the left in injuries to the precordium, is more appropriate than a posterolateral thoracotomy, as it can be rapidly extended to a clamshell approach for maximal access to the pericardium and both pleural cavities.

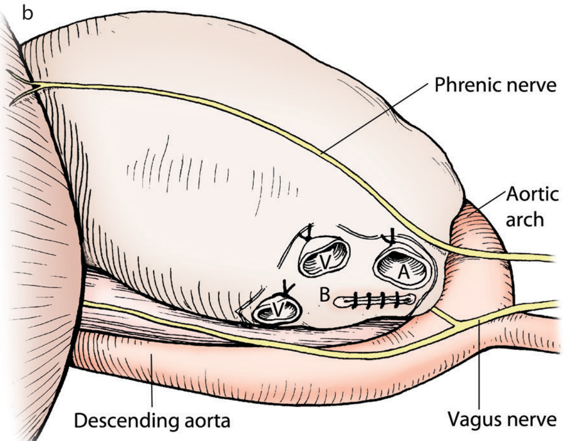
A severed intercostal vessel is simply ligated. A bleeding lung laceration will usually have within it a vessel that can be secured. The remaining laceration is then oversewn or stapled to reduce haemorrhage and air leak, and the chest closed with chest drains. A severe injury to a lung hilum may be from penetrating trauma or a deceleration shearing force. The vessels and bronchus may be partially avulsed, and the only way of controlling haemorrhage may be to complete the pneumonectomy. A Satinsky clamp applied around the vessels and bronchi in the hilum may give temporary control, but pulmonary veins avulsed from the left atrium are particularly difficult to control, repair or close. A general surgeon faced with this situation can do little more than follow general surgical principles in attempting to secure control. The anatomy of the hila is shown in Figure 8.11.

CARDIAC TAMPONADE AND CARDIAC INJURY

Urgent operative intervention is the only effective intervention in all cardiac wounds and it will not be possible to stabilise a patient for transfer to a cardiothoracic unit.[8] A small laceration to the heart from either penetrating or blunt trauma



Right hilum



Left hilum

Figure 8.11 *Hilar anatomy. The bronchi (B) lie posteriorly and are shown closed in a linear fashion. The pulmonary arteries (A) lie immediately anterior to the bronchi and the upper and lower pulmonary veins (V) lie more inferior. All vessels are shown ligated. The phrenic nerves lie anterior to the hila, on the pericardium. The vagus nerves lie posterior to the hila, in association with the oesophagus. (a) Right hilum: the azygos vein curves over the hilum to the superior vena cava. It lies lateral to the right vagus nerve and obscures it from view. (b) Left hilum: the aortic arch curves over the hilum to continue as the descending aorta. It partially obscures the oesophagus but the left vagus and recurrent laryngeal nerve are vulnerable as they cross the lateral aspect of the aortic arch.*

can bleed into the pericardial sac, but this may remain contained by the pericardium. Blood collects under pressure, compresses the heart and prevents cardiac filling. In a classic case of cardiac tamponade, there is hypotension, dilated neck veins and muffled heart sounds. An X-ray shows a bulbous outline to the cardiac shadow. More often, the situation is confused by multiple intrathoracic injuries, and may be missed until it presents acutely with electromechanical dissociation in a 'cardiac arrest'. The pulseless patient with a beating heart has either exsanguinated or has a failure of cardiac filling due to cardiac tamponade. Without release of the tamponade the patient will die of what might be only a minor cardiac injury. Pericardial aspiration is inappropriate in trauma, as the underlying cardiac laceration will almost certainly re-bleed. The correct management is exposure of the heart, either through a left (or right) anterolateral thoracotomy, depending on the side of the injury, and to proceed to a clamshell if necessary. A median sternotomy also offers excellent exposure, but the approach is unfamilar to most general surgeons and typically requires a pneumatic powered sternal saw, which is often unavailable outside of a cardiothoracic unit.

The pericardium is opened anteriorly and parallel to the phrenic nerve, and blood under pressure is released. Once the pericardium is opened, the tamponade is relieved and cardiac output increases, with a resultant fall in venous pressure. Bleeding from the laceration is therefore often very minimal, and suturing of the laceration may be relatively simple. Cardiac wounds can be controlled initially by digital pressure. The commonest site for bleeding is the right ventricle; injury to the right atrium does occur but less often. Both are thin-walled chambers and are easily sutured. Occasionally, it may be possible to isolate an atrial laceration with a side occlusion clamp while the laceration is repaired. A 4/0 Prolene™ vascular suture is suitable for the atrial wall. A buttressed, pledgetted suture of heavier 3/0 Prolene™ is recommended for closure of a laceration of ventricular muscle. When suturing a ventricular laceration care must be taken not to tie the coronary arteries on the epicardium of the heart. This can be avoided by placing a pledgetted horizontal mattress suture across the laceration and underneath the coronary artery. The surgeon should check the posterior aspect of the heart before concluding the operation in order to exclude a through-and-through injury, particularly in penetrating trauma.

MEDIASTINAL BLEEDING AND MAJOR VESSEL TRAUMA

In blunt trauma, bleeding from the disruption of a major vessel may be contained initially by intact adventitia and surrounding tissue. At this stage there is no gross loss of circulatory volume. An X-ray finding of a widened superior mediastinum from haematoma may be the only indication of a ruptured aorta or of a major artery avulsed from the aortic arch. The challenges in interpreting emergency supine X-rays make the diagnosis more difficult, as a supine anteroposterior film makes the mediastinum look enlarged. Early diagnosis is essential if this window of opportunity for the transfer of such patients to a cardiothoracic unit is not to be lost. In penetrating injuries to major vessels an initial period of stability is less likely.

Occasionally, a general surgeon is forced by circumstance to operate. Unfortunately, the injuries encountered are commonly beyond both the skills of the surgeon and the limitations posed by the absence of cardiopulmonary bypass facilities. The choice of incision will depend on the likely site of injury. For example, if the patient has an anterior bullet wound, an anterolateral thoracotomy, which can be extended to a clamshell thoracotomy, may be the most appropriate. A vertical median sternotomy will give superior access to the vessels of the superior mediastinum and can, if necessary, be extended into the neck but, as discussed above, may be a more difficult incision in an emergency. When an injury to the descending aorta is suspected, a left posterolateral thoracotomy will give best access.

Major vessel trauma in the superior mediastinum is extremely challenging, and a surgeon inexperienced in thoracic surgery will be most unlikely to succeed. The anatomy will be distorted by haematoma, and the trauma is seldom confined to the vessels. In penetrating trauma, the knife or bullet may also have transgressed the respiratory tree, the oesophagus or the spinal cord. In closed trauma, the shearing and traction forces may also have damaged adjacent structures. For example, an avulsion injury of the subclavian artery from the aortic arch is frequently associated with a traction injury to the brachial plexus.

A horizontal deceleration injury causes rupture of the thoracic aorta just distal to the origin of the left subclavian artery. Most (80 per cent) die from this injury in the first hour and 80 per cent of the remainder die within the next 24 hours. Transfer is usually possible if this injury is diagnosed while the bleeding is still contained. However, if this opportunity has passed, a general surgeon may have to attempt a repair, though success is rare outside a cardiothoracic unit. Isolation of the injury for haemorrhage control and repair is hampered by the origins of major arteries, the need to maintain carotid perfusion and the problems associated with high aortic cross-clamping(see Chapters 6 and 7).[9]

In the absence of cardiopulmonary bypass equipment, a 'clamp and go' technique, with its attendant risk of paraplegia, is the only option. A proximal clamp is placed across the base of the left subclavian artery and the aorta. A large soft clamp as used in bowel surgery is suitable for this. A second clamp is placed on the descending aorta, and a vasodilator such as nitroprusside is used to lower the blood pressure while the lesion is repaired. Unfortunately, in most instances the tension on the suture line makes it essential to use a prosthetic aortic graft, which is unlikely to be available in a nonthoracic centre in an emergency setting.

Major vessel injury in the posterior mediastinum is more accessible. It may be possible to suture a simple laceration of the descending aorta or the inferior vena cava. When a more extensive reconstruction or repair is required, the aorta may require to be cross-clamped and a temporary Gott shunt from the arch to the descending aorta should be considered.

Major air leaks

Major air leaks can be divided into those from lung and those from the trachea or major bronchi.

LUNG LACERATIONS

Most air leaks from damaged lung seal spontaneously, and can be successfully managed in the interim by intercostal underwater seal drainage. Large, deep lacerations produce high-volume air leaks and are associated with considerable haemorrhage. These lesions require urgent surgery. In lung lacerations not requiring urgent surgery, incomplete re-expansion of the lung and persistent air leak beyond 3 days is an indication for surgical repair, as uncontrolled air leak and persistent pneumothorax will result in an empyema.

TRACHEOBRONCHIAL LACERATIONS AND RUPTURES

Tracheobronchial injuries are rare but they are life-threatening injuries with variable presentation.[10] In a penetrating injury air is usually escaping through the wound. In the absence of associated vascular or oesophageal injuries, small lacerations to the trachea can be managed conservatively, but large-volume air leaks may require sutured closure. Penetrating injuries to the carina and main bronchi are almost always associated with major vessel damage and the necessity for emergency thoracotomy.

Following blunt trauma with bronchial rupture, the extreme presentation is with a massive pneumothorax and a completely deflated ipsilateral lung. However, a mucosal tear allows escape of air only into the bronchial wall. The intramural air and blood may obstruct the bronchus with resultant collapse of the lung or, if more minor, may present late with a bronchial stenosis.

Stable patients with a suspected tracheobronchial rupture should be referred to a thoracic surgical unit. However, patients with major disruption of the trachea or carina may require immediate intervention if ventilation cannot be maintained. Endotracheal mechanical ventilation may also fail with a complete major bronchus disruption, as the resistance preventing air from escaping into the pleural cavity and out through the chest drain is less than that required to inflate the contralateral lung. Temporary control of the situation should be possible with a double-lumen endotracheal tube or even a single-lumen tube advanced into the intact side.

Only rarely will the general surgeon have to operate. Injuries to the cervical and proximal two-thirds of the thoracic trachea are accessible through a cervical collar type incision. Injuries to the lower third of the trachea, carina and right main bronchus are best approached through a right thoracotomy. Injuries to the left main bronchus are much more difficult. They are approached through the left chest and require mobilisation of the aortic arch. Repair is with interrupted non-absorbable sutures. When there is also major hilar haemorrhage from a partially avulsed lung, a pneumonectomy may be the only solution.

Oesophageal injuries

The surgical management of intrathoracic oesophageal injuries, including iatrogenic and spontaneous perforation, is discussed in Chapter 18.

SURGERY FOR NON-TRAUMATIC CARDIOTHORACIC EMERGENCIES

Most of the cardiothoracic surgery that a generalist can usefully undertake has already been described. There are, however, some surgeons who wish to offer a thoracic surgical service in addition to general surgery. Additional cardiothoracic surgical training will be necessary. The surgical management of bronchiectasis and lung cancer, in addition to the operative details for an elective lobectomy, will be important for such surgeons but their inclusion in a general surgical operative text would be inappropriate.

Thoracic emergencies

Two non-traumatic thoracic emergencies for which a surgical option is possible should be discussed. Pulmonary embolus and massive haemoptysis are life-threatening intrathoracic emergencies. They are both common conditions and may occur in hospitals far from a cardiothoracic unit.

PULMONARY EMBOLECTOMY

This is an operation that many surgeons can describe but few have performed or even seen undertaken, despite the fact that many patients die suddenly in hospital from a pulmonary embolism. The indications for surgery are, however, difficult to establish, and the window for useful intervention is very narrow. Surgery can only realistically be undertaken once the patient has been transferred to the operating theatre, and most patients who have survived the initial embolic event survive without surgery. Thrombolytic therapy is thus normally the management of choice. A median sternotomy is followed by isolation of the pulmonary trunk, around which tapes are passed for vascular control. An arteriotomy is performed and the clot aspirated, thereby relieving the acute right heart outflow obstruction. The arteriotomy is then sutured.

HAEMOPTYSIS

A massive haemoptysis can be life threatening owing to asphyxiation or to blood loss but the prognosis is related partly to the rate of bleeding. For example, a mortality of 71 per cent has been reported when expectoration exceeded 600 ml blood in 24 hours. Three per cent of patients with lung cancer will have a massive haemoptysis but inflammatory lung diseases, such as tuberculosis and bronchiectasis, are the most common causes. In countries with a high incidence of tuberculosis this is a common emergency, often presenting in hospitals at a distance from cardiothoracic units. Recurrent, and even fatal, massive haemoptysis may occur in around a third of patients within the following 6 months if definitive management of the bronchial arteries has not been undertaken.[11]

Immediate intubation is indicated if the airway is threatened. A double-lumen endotracheal tube has the advantages that it allows isolation of the lungs and affords protection of the non-bleeding side. Adequate sedation is essential to prevent coughing and straining. Endobronchial intervention, such as balloon tamponade, is only possible where facilities and experience exist. Bronchial artery embolisation is the intervention of choice in many units with a high incidence of tuberculosis. It is sometimes only partially effective and unfortunately late recurrence is also common.[11,12] It does, however, allow stabilisation of the situation so that the patient can be transferred to a specialist unit. Emergency surgery for massive haemoptysis is technically too challenging to be an option for a surgeon without thoracic training.

Cardiac emergencies

Two non-traumatic cardiac emergencies that are relatively common in the developing world should be mentioned. Both present with severe cardiac failure from a remedial mechanical cause, and often occur in young people. As neither requires open-heart surgery, intervention can be considered, but only if transfer is impossible.

CONSTRICTIVE TUBERCULOUS PERICARDITIS

Constrictive tuberculous pericarditis presents with worsening heart failure as the heart is prevented from filling by the fibrous constriction of the pericardium. Surgery consists of stripping off the adherent pericardium overlying the left heart through a thoracotomy or by a median sternotomy, which affords better access but is more hazardous due to dense adhesions over the heart. Care must be taken to avoid injury to the coronary arteries. Unfortunately, a left thoracotomy without skilled anaesthetic and intensive care facilities may be an unsurvivable insult to these very sick patients, and this is not an operation that can be recommended with any enthusiasm outside of a cardiothoracic unit.

MITRAL STENOSIS

The onset of left heart failure may be very sudden and is sometimes precipitated by the increased cardiac output in the mid trimester of pregnancy. Pulmonary oedema may be uncontrollable and, without intervention, death inevitable. A balloon valvotomy is now an option if the radiological skills and endovascular equipment are available. When they are not, and referral for specialist assessment and intervention is not possible either, the old technique of closed mitral valvotomy may still be appropriate. The stenosis in these young patients is a sequela of rheumatic fever, and the valve cusps, although fused, are pliable and otherwise free of degenerative disease. The cusps can be split along the line of fusion either by a dilator introduced through the apex of the left ventricle or by a finger inserted through a left atrial purse-string suture, or a combination of the two techniques (Figure 8.12). The possibility that the cusps could be separated was suggested in 1902 and was first carried out successfully in 1925.[13,14] This should therefore still be a possible, albeit high-risk, option for a surgeon with no access to cardiac centre referral.[15]

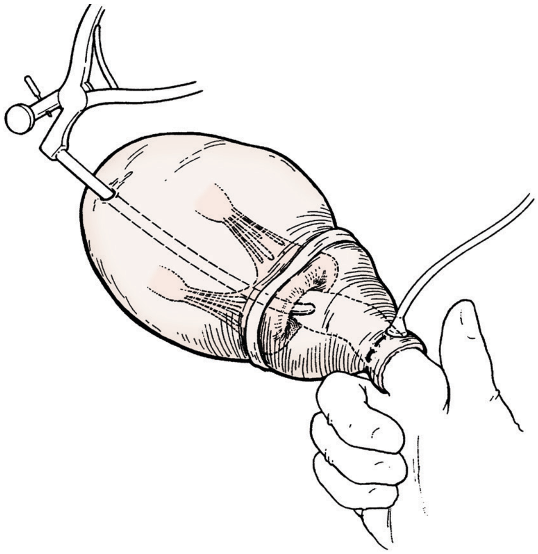


Figure 8.12 *A closed mitral valvotomy with a transventricular dilator guided by a finger in the left atrium.*

INTRATHORACIC VASCULAR, OESOPHAGEAL AND PAEDIATRIC SURGERY

Vascular surgery is discussed in Chapters 6 and 7 and oesophageal surgery in Chapters 17 and 18.

Paediatric cardiothoracic surgery

The surgical principles in the management of infection, including tuberculosis, are similar in the child and in the adult, and the surgical issues in thoracic trauma are also similar, although the spectrum of injury may differ. For example, in a thoracic crushing injury the greater pliability of the child's thoracic cage may allow serious damage to the intrathoracic viscera in the absence of fractured ribs.

General paediatric surgical practice includes the surgery of congenital diaphragmatic hernia and oesophageal atresia, and the surgical management of these conditions is described in Chapters 13 and 18, respectively. The paediatric surgeon with a large neonatal referral base will thus be familiar with intrathoracic surgical techniques, but these neonatal intrathoracic operations are unlikely to be successful in conditions where general surgeons are forced to attempt them.

Congenital cardiac abnormalities are common, and most are managed optimally by early major surgery in which a definitive procedure is carried out before there is secondary tissue damage. When definitive surgery was not undertaken until later in childhood, simple holding procedures were undertaken, included banding of the pulmonary artery to limit excessive pulmonary blood flow and the Blalock–Taussig shunt to increase pulmonary blood flow. Although both operations could be undertaken by a generalist, they are no longer indicated. The repair of a patent ductus arteriosus or a coarctation of the aorta might be achievable by a generalist when no referral is possible, but surgical correction of other anomalies would not be a viable option in such surroundings.

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9

NEUROSURGERY FOR THE GENERAL SURGEON

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The care of patients with head injuries is frequently undertaken by general surgeons who, with their anaesthetic colleagues, undertake both the monitoring and non-operative management of the patient with intracranial trauma. Only a small minority of patients will require transfer to a neurosurgical centre for surgical intervention. It is therefore important that those caring for such patients understand the pathology of injury to the brain and the indications, benefits and limitations of intracranial surgical intervention. The operative management of scalp wounds associated with minor head injuries will remain the responsibility of the general surgeon, and it is again these surgeons who most frequently undertake minor elective surgery on the scalp.

Few general surgeons practising in the developed world anticipate a circumstance in which they will have to open the cranium. If such an emergency should arise, where transfer to a neurosurgical unit is not possible, the surgeon would be advised to seek telephone guidance from a neurosurgeon. However, the truly isolated generalist without the benefit of specialist support occasionally can offer a simple effective neurosurgical operation. It is for such surgeons that this chapter is predominantly written.

ANATOMY

SCALP

The various layers of the scalp are shown diagrammatically in Figure 9.1. The *galea aponeurotica* is a thin but dense aponeurosis into which are inserted the frontal and occipital muscles. Its lateral margins blend with the strong temporal fascia. The skin of the scalp is bound to the underlying aponeurosis by a layer of dense fibrous connective tissue, in which lie the vessels and nerves. These three outer layers of the scalp move as one and are separated from the pericranium by a layer of loose areolar tissue.

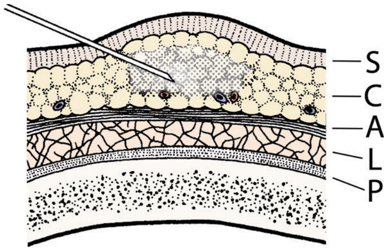

Figure 9.1 *The layers of the scalp. S = skin; C = connective tissue; A = galea aponeurotica; L = loose areolar tissue; P = pericranium. Local anaesthetic injections should be superficial to the aponeurosis.*

CRANIUM AND DURA MATER

In the adult the individual skull bones are fused and form the boundaries of the rigid intracranial compartment. The pericranium is the periosteum on the external surface of the skull. It is continuous with the outer layer of the dura at the foramen magnum and is attached to the cranium at the sutures between skull bones. Unlike periosteum elsewhere, it is easily stripped off the underlying calvarial bone and contributes very little to the blood supply of the bone, which is mainly from meningeal arteries. The dura forms a dense fibrous covering to the brain and spinal cord. Within the cranium the dura consists of two layers closely bound together, the outer of which represents the periosteum on the internal surface of the bone. The meningeal arteries lie extradurally on the outer surface of the dura between the dura and the bone. Folds of the inner layer of the dura partially divide the intracranial space into supra- and infratentorial compartments, and the supratentorial compartment into two right and left spaces. The two layers of intracranial dura separate to enclose the cranial venous sinuses (Figure 9.2). The subdural space is a potential space between the dura and the arachnoid mater.

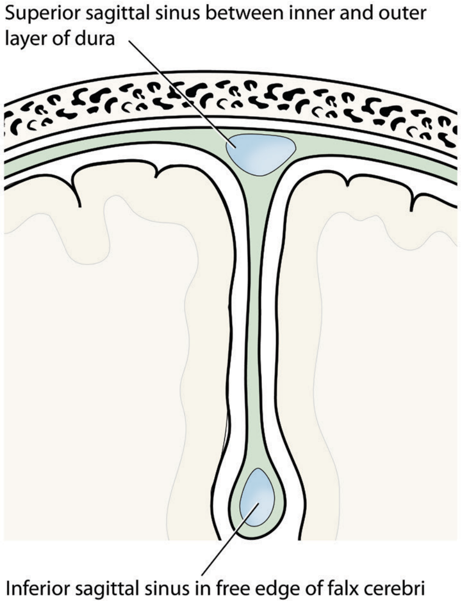
Superior sagittal sinus between inner and outer layer of dura
Inferior sagittal sinus in free edge of falx cerebri

Figure 9.2 *The two dural layers split to enclose the venous sinuses. The folding of the inner layer forms the falx cerebri and the tentorium cerebelli.*

ARACHNOID MATER

The arachnoid mater is a very thin membrane covering the brain and spinal cord. It is separated from the pia mater, which is on the surface of the brain and spinal cord, by the subarachnoid space in which cerebrospinal fluid (CSF) circulates. This space is in direct communication with the ventricular system of the brain.

SCALP SURGERY

Local anaesthesia

Minor surgery on the scalp includes the removal of skin lesions and the debridement and closure of lacerations. Surgery is usually performed under local anaesthesia, which should be infiltrated into the connective tissue layer, within which lie the superficial nerves. If there is little resistance to the injection, it implies that the solution is diffusing into the loose areolar tissue beneath the aponeurosis and that skin anaesthesia will be poor.

Control of haemorrhage

The scalp has a rich blood supply and brisk bleeding occurs from any incision. Individual bleeding points are often difficult to identify and control in the dense fibrous layer of the scalp. Fortunately, although initial bleeding from a scalp laceration may be profuse, it has often stopped spontaneously by the time a patient reaches medical attention. Whenever possible, operative incisions should be made vertically, in line with the main vessels. Bleeding is reduced if the incision is made with diathermy, but larger vessels will still bleed and are difficult to pick up in forceps. In minor excisional surgery, digital pressure on the scalp lateral to the wound while surgery is completed, followed by deep sutures and pressure to the sutured wound, is often sufficient to control bleeding. In the more major scalp incisions for neurosurgical access (Figure 9.3), bleeding from the scalp edges must be controlled during surgery. Initial control by finger pressure on the adjacent scalp can be followed by pressure with Raney clips (Figure 9.4). Alternatively, a series of artery forceps is applied to the galea aponeurotica at 1-cm intervals and then pulled back so that the galea is drawn over the cut surface, stretching and occluding the bleeding vessels.

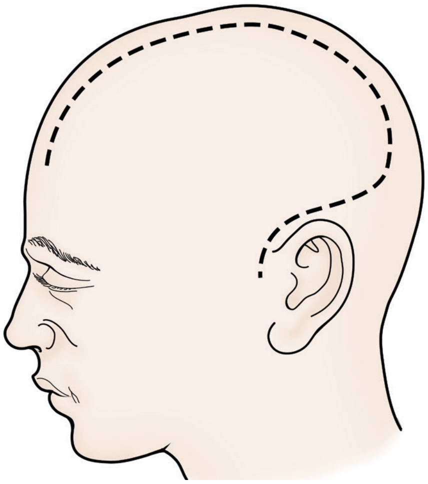

Figure 9.3 *A scalp flap, which will allow extensive access to the lateral skull.*

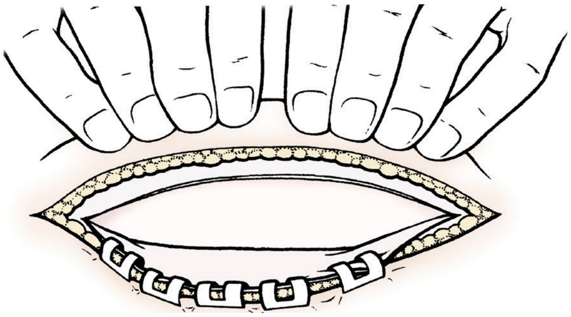

Figure 9.4 *Finger pressure will reduce bleeding from a scalp incision until Raney clips can be applied to the cut edge. Clips used to draw the aponeurosis over the skin edge are an alternative.*

Closure of scalp wounds

Similar principles apply to surgical incisions and traumatic wounds in the scalp. The scalp is thick and the cut edges are often still bleeding when the surgeon is ready to close an incision. Therefore, deep full-thickness simple or mattress sutures, which compress the skin and subcutaneous fibrous connective tissue layer, are ideal. If the scar will later be covered by hair, any additional scarring attributable to the sutures will not be visible. Separate absorbable deep sutures in the galea are recommended in long wounds (Figure 9.5). Scalp apposition, after either traumatic tissue loss or after the excision of a skin lesion, can be surprisingly difficult considering the apparent mobility of the scalp. Some tension on the suture line is permissible, as the scalp has an excellent blood supply. However, if tension is unacceptable, a rotational flap may be used. A skin graft will give a bald patch, which is often cosmetically unacceptable, but occasionally this may be the only immediate solution. A bald patch from the healing of a scalp defect or burn can be excised later and hair-bearing scalp mobilised and rotated; a large defect may be covered by adjacent hair-bearing skin if the available tissue has been increased by an implantable tissue expander (see Chapter 2).

Scalp flaps for neurosurgical access

These U-shaped flaps are most commonly reflected on an inferior pedicle, which is based on the vascular anatomy of the scalp. The incision through the aponeurosis is in line with the skin incision, and the flap is reflected in the subaponeurotic plane to expose a large area of cranium (Figure 9.6). When frontal bone exposure is required, the incision for the flap should be sited within the frontal and temporal hairline so that the scar is inconspicuous.

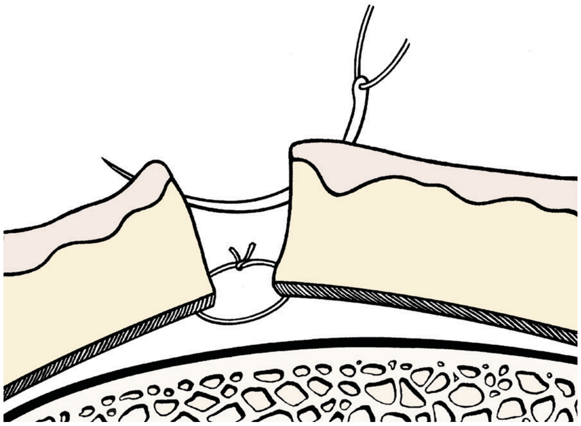

Figure 9.5 *Scalp wounds more than a few centimetres in length require separate closure of the aponeurotic layer.*

Scalp trauma

The significance of a small scalp wound is difficult to assess without knowing the nature of the injury. For example, a laceration with a broken glass bottle can confidently be assumed to involve only damage to the scalp, whereas a scalp split at the point of contact from a golf club or similar small blunt object may be associated with an underlying skull fracture. This fracture will be compound and it may be depressed. In a major acceleration–deceleration injury, a scalp laceration at the point of contact with the ground or with a windscreen may have no underlying fracture, or there may be an extensive ‘eggshell fracture’ involving a large area of cranium.

The possibility of a penetrating brain injury must not be overlooked. It may be obvious in a machete attack producing a large wound with extruding brain tissue, or external signs may be more subtle and a reliable history not obtainable. The entry wound of a bullet may be small and not easy to differentiate from an insignificant scalp laceration until the wound is cleaned and the hair shaved. An entry wound through the orbit, nose, ear or nasopharynx may not be immediately apparent.

Skull X-rays should be taken if there is any likelihood of a fracture underlying a scalp wound. A significantly depressed fracture, particularly one under a scalp wound, suggests a penetrating injury needing referral for specialist assessment. A scalp wound without an underlying fracture or with a simple undisplaced fracture usually requires only wound toilet and closure.

When dealing with an apparently simple laceration, an unsuspected fracture is occasionally found. If the fracture feels undisplaced, the scalp should be closed after wound toilet and debridement. If, however, the fracture appears displaced or a penetrating injury is now suspected, no further wound toilet, exploration or probing is appropriate until a skull X-ray or CT scan is performed and a review of the mechanism of injury is obtained, because neurosurgical referral may be more appropriate. Antibiotic prophylaxis should be started.

Scalp infection

A *subgaleal abscess* is a diffuse collection of pus in the loose connective tissue between the galea and the pericranium. It most often follows a deep, neglected, contaminated scalp wound. Once infection is established it may spread in this plane to involve the entire scalp. Usually, the original wound is obviously infected and pus may drain through it spontaneously. Improved drainage is the first priority. This may be possible by enlarging the original wound and irrigating the whole space. Alternatively, and especially if there are loculations, additional incisions should be made. Antibiotic therapy is less important than adequate drainage, but is indicated if there is associated cellulitis of the scalp.

SURGERY OF THE CRANIUM

Surgery of the cranium divides into management of fractures and surgery for intracranial access.

Skull fractures

Skull fractures may involve the calvarium and/or the skull base. A skull fracture is an indicator of a significant force imparted to the head. The only importance of the fracture itself is in its potential to damage the underlying brain, either directly or indirectly.

SIMPLE UNDISPLACED SKULL FRACTURES

No specific treatment is indicated. However, a fracture that traverses a vascular skull mark, such as that of the middle meningeal artery, increases the risk of an extradural haemorrhage.

COMPOUND UNDISPLACED SKULL FRACTURES

An overlying scalp wound is cleaned and closed and the patient started on broad-spectrum antibiotics, as there is a danger of intracranial infection. It must be remembered that even without an external wound, skull base fractures into the sinuses, middle ear and nasopharynx are compound, with a risk of intracranial infection. Accordingly, antibiotic prophylaxis is usually given to any patient with a basal fracture of the skull or a fracture through the frontal sinus, and to any patient with a head injury who has bleeding from the ear or has CSF rhinorrhoea or otorrhoea. However, there is still some controversy over this antibiotic policy. CSF rhinorrhoea or otorrhoea usually will cease spontaneously, but occasionally, if CSF leakage is persistent and profuse or when a pneumatocoele develops, it may be necessary to close the CSF fistula either intracranially (with a dural graft) or extracranially (as an ENT procedure).

SUBPERIOSTEAL HAEMATOMAS

A swelling, if accurately confined to the area of one skull bone, is usually associated with an underlying skull fracture. The haematoma is contained by the fusion of the pericranium to the underlying bone at the fissures. As the haematoma is organised and absorbed, palpable ridges develop at its edges, which can mimic the edge of a depressed skull fracture. No action is required. A *subperiosteal abscess*, associated with osteomyelitis of a cranial bone, produces a similar localised swelling ('Pott's puffy tumour'). Treatment is by drainage of the pus, possibly removal of infected bone and appropriate antibiotics.

DEPRESSED SKULL FRACTURES

In most instances these occur without a significant overlying wound, are not grossly displaced and, more importantly, the minor displacement has seldom resulted in spicules of inner skull table being driven through the dura into the brain. Elevation of these minor depressed fractures is recommended mainly for cosmetic considerations when they are in the frontal region. There are, therefore, few instances where intervention by an isolated generalist would be justified. For the forehead, the most cosmetically acceptable scalp flap will be with the incision within the hairline. This can give extensive exposure of the frontal bone. Figure 9.6 illustrates the classical method of elevating a small depressed fracture through a burr hole immediately adjacent to the fracture. This is now known to be dangerous, as it increases the risk of inadvertent brain penetration. The burr hole should be made on stable bone with 1–2 cm of stable cranium separating it from the fracture. Great care must be taken not to tear the intact dura. The technique is also dangerous in the proximity of the dural sinuses. Many closed injuries that are suitable for this operation could be safely left alone.

Severe comminuted depressed skull fractures are an integral part of a penetrating head injury. The dura is torn and spicules of bone will have been driven into the underlying brain substance. Exploration is indicated to remove spicules of bone, hair, missiles, metal and contaminated vegetable matter, and this is discussed further below. Very occasionally, a skull X-ray indicates a similar fracture with spicules of in-driven bone but without an open wound. Exploration is again necessary for their removal. Severely displaced fractures with dural tears cannot be simply levered back into position, and a craniotomy is usually necessary for adequate access.

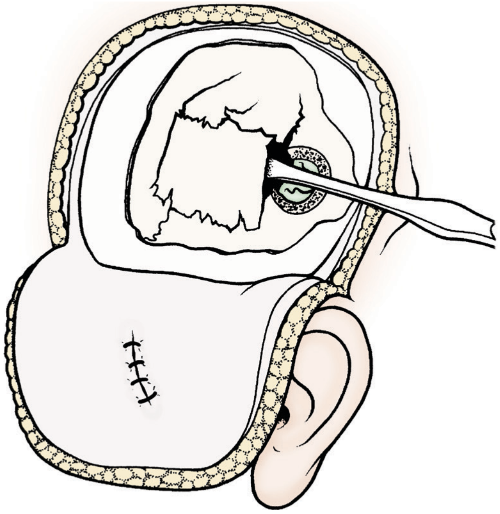

Figure 9.6 *'How not to do it'. This traditional method of levering a depressed skull fracture back into place is inherently dangerous, especially when the burr hole is made, as illustrated, either over or immediately adjacent to the fracture. The burr hole should be separated from the fracture by 1–2 cm of stable bone.*

Intracranial access

The simplest intracranial access is via a *burr hole*, but access is limited. This can be extended by enlargement of the burr hole with rongeur forceps to create a larger *craniectomy* (Figure 9.7). Access is still somewhat limited, and the larger defect in the cranium is unsatisfactory in the long term and may have to be addressed later. The alternative *craniotomy* involves removal of a plate of bone, which is replaced at the end of the operation.

BURR HOLE

The temple is a common site for a burr hole. However, the principles are the same when burr holes are made in other parts of the cranium.

In the temple, *the scalp incision* is from the lower border of the zygoma, halfway between the eyebrow and the meatus, and runs upwards and slightly backwards for about 5 cm (Figure 9.7a). If a surgeon anticipates that a craniotomy may prove necessary, this incision, and those of any subsequent burr holes, should be modified so that they can be incorporated into a scalp flap incision. The superficial temporal artery may be either ligated or coagulated. In the lower part of the wound the temporalis muscle, covered by fascia, is incised and the muscle and periosteum split down to the bone. A strong self-retaining retractor is then placed to hold the muscle fibres apart (Figure 9.7b).

The *burr hole* is classically made immediately above the midpoint of the zygomatic arch, but unstable bone immediately adjacent to a fracture should be avoided. A perforator on a Hudson brace (Figure 9.8), or a more modern equivalent if available, is used. The perforator should be turned rapidly with *gentle* inward pressure (at right-angles to the bone surface) to prevent sudden perforation of the bone. When the inner table is penetrated, a characteristic rocking or juddering sensation is produced. The perforator should then be replaced with a burr and the hole enlarged. Because the burr tapers and cuts a funnel-shaped hole, it is safe to use, but the surgeon should still be careful not to plunge the instrument intracranially, especially through the thin bone of the temporal fossa.

At the end of the procedure, the bony defect of a burr hole can be ignored and the scalp closed in two layers over it. When a burr hole has been extensively enlarged as a craniectomy, the defect may require a later cranioplasty.

CRANIOTOMY

A formal craniotomy is required when intracranial surgery requires access greater than that possible through a burr hole and limited craniectomy. Originally, a single osteoplastic flap, with the scalp left attached to the bone, was used, but it is now usual to raise scalp and bone flaps separately. The bases of the two flaps do not need to coincide. A scalp flap suitable for a large craniotomy is shown in Figure 9.3. It is reflected by

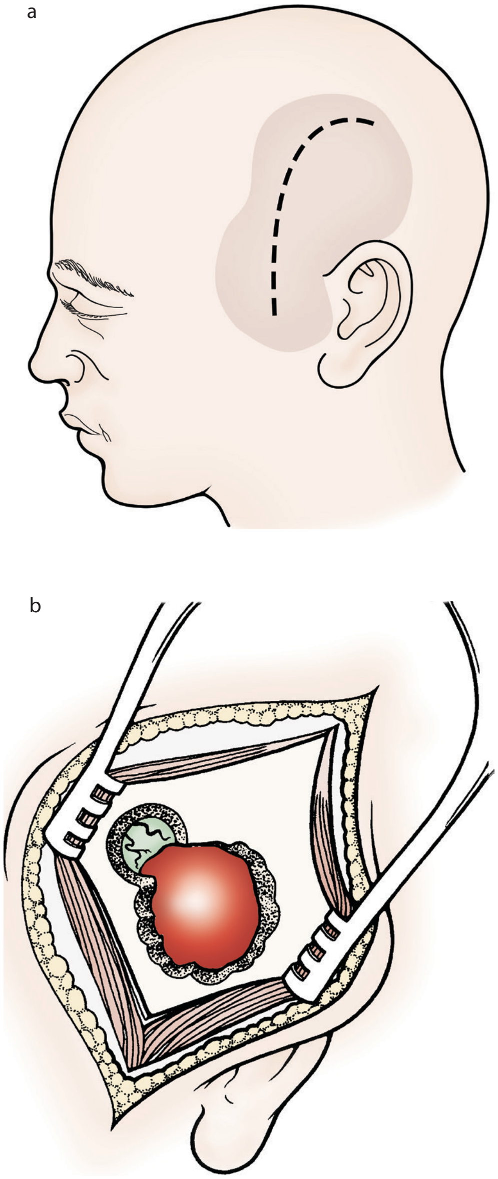

Figure 9.7 *(a) The surface marking of the incision for exploration of a suspected extradural haematoma in the temporal region. (b) The temporalis muscle is split and held apart by a self-retaining retractor to expose the temporal bone. The initial burr hole has been enlarged with a bone rongeur.*

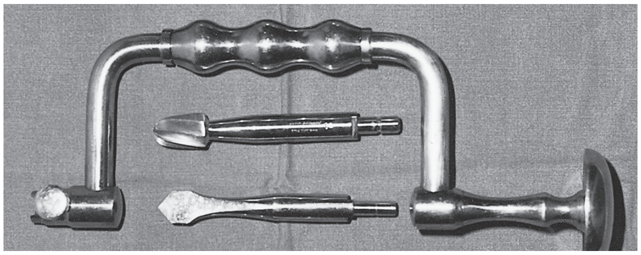

Figure 9.8 *A Hudson brace with skull perforator (below) and burr. These are the basic traditional instruments that will probably be available to the general surgeon who has to open the cranium.*

separation through the loose areolar layer beneath the galea aponeurotica. To create a bone flap the calvarium is cut to connect a series of burr holes. Neurosurgeons use a craniotome but if this is not available, or the operating surgeon is not familiar with its use, a Gigli saw will accomplish the same task. By means of a special guide, it can be passed between burr holes, with care being taken to avoid dural injury, and the intervening bone divided. An outward bevel is important so that the freed portion of skull, when replaced, will not sink below its normal level. The two holes at the base of the flap are placed closer than the others so that the narrow base can be nibbled across more easily with a bone rongeur. The bone at the base of the flap can be cut across or fractured, but left attached by pericranium or temporalis muscle as a *pedicled bone flap*, which is then lifted off the dura (Figure 9.9). Alternatively, the skull bone and periostium are completely divided and the *free bone flap* lifted out of the wound and temporarily wrapped in moist gauze. At the completion of the operation, the skull flap is replaced and held in position with sutures joining the pericranium on the bone flap to pericranium on the adjacent skull.

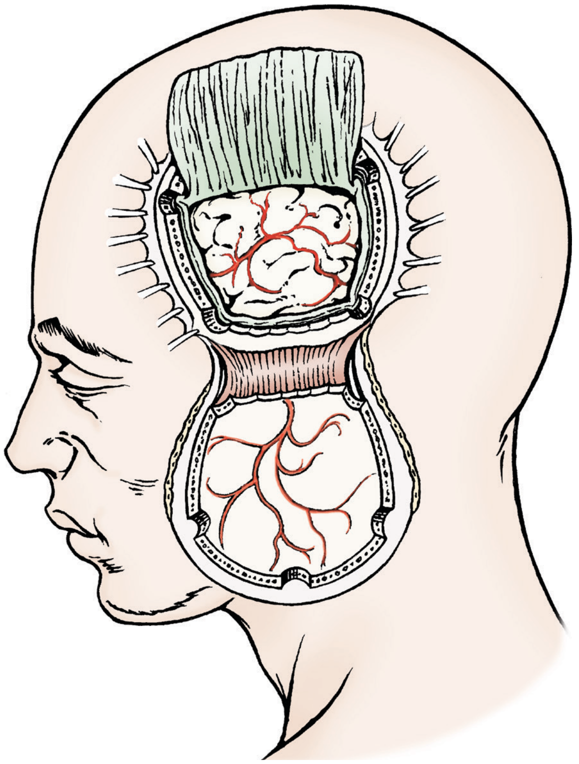

Figure 9.9 *A parietal bone flap has been raised by division of the skull between burr holes. It has been elevated as an osteoplastic flap still attached by the temporalis muscle. The dural flap has then been raised with its base towards the sagittal sinus.*

Cranial defects

Cranial defects may be due to removal of bone fragments in comminuted or depressed fractures, or they may be the result of extensive enlargement of a burr hole. Repair by bone graft or by the implantation of a titanium or acrylic plate may be desirable to protect the brain from subsequent injury, but this surgery should be postponed, commonly for at least 6 months, to minimise any risk of infection.

INTRACRANIAL SURGERY

The intracranial surgery of malignant, vascular and degenerative pathology is not included in this chapter, as it is a field in which the intervention of a general surgeon would be inappropriate. However, when confronted with cases of sepsis or trauma, a general surgeon who is unable to transfer a patient to a neurosurgeon may be able to offer an effective intracranial operation. This surgery includes drainage of intracerebral pus, exploration of a penetrating cerebral wound and evacuation of a space-occupying, post-traumatic intracranial haematoma.

Drainage of intracranial pus

INTRACEREBRAL ABSCESS

Intracerebral abscesses may develop by haematogenous spread from a distant source of infection such as an infective vegetation on a damaged aortic or mitral valve. They may also occur secondary to penetrative trauma or to untreated infection in a frontoethmoid or mastoid sinus. Treatment consists of drainage of the abscess with a wide-bore needle introduced through a burr hole (Figure 9.10). The wall of the abscess, which is often encapsulated, is felt as a characteristic resistance, and when this is penetrated the pus oozes out under pressure through the needle. An appropriate antibiotic regime is instituted and repeat aspiration may be necessary.

The major difficulty for a surgeon without sophisticated imaging is to confirm the diagnosis and localise the abscess. There may be localising neurological signs, but there may only be evidence of infection and raised intracranial pressure. An abscess secondary to a sinus infection is commonly in the adjacent lobe of brain,[1] but blind needling for intracerebral pus through an exploratory burr hole without CT confirmation is not a comfortable situation. It should only be considered if neither referral nor imaging is possible.

SUBDURAL EMPYEMA

Infected collections in the subdural space are mostly secondary to penetrative trauma or occur as a result of the extension of an untreated infection in the air sinuses or middle ear. The patient classically shows evidence of an infective pathology and also has focal neurological signs such as a hemiplegia or epileptic convulsions; these are due to inflammation in the underlying cortex or thrombosis within underlying cortical veins. Treatment is by drainage of the pus, combined with antibiotic and anticonvulsant therapy. Commonly, a neurosurgeon will evacuate subdural pus through a craniotomy,

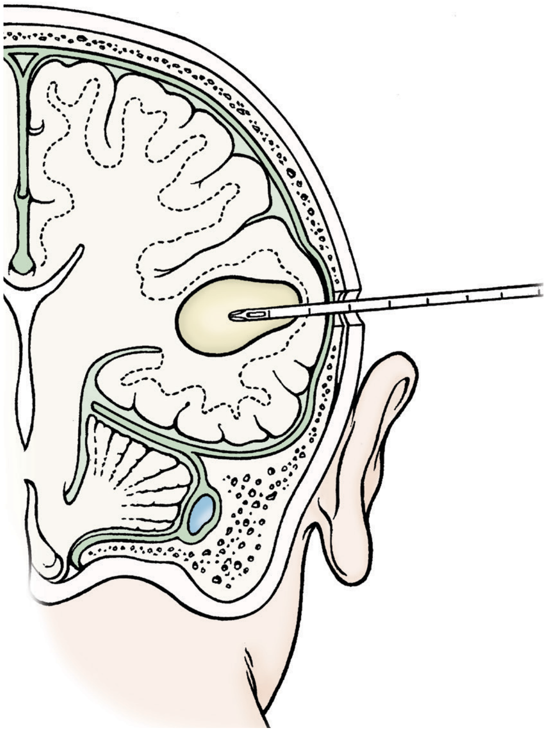

Figure 9.10 *An intracerebral abscess can be drained with a wide-bore needle introduced through a burr hole.*

although this may also be possible through multiple burr holes.[1] The dura at the bottom of each burr hole is opened with a cruciate incision, the brain gently depressed (for example, with a smooth periosteal elevator or broad, curved dissector) and the subdural pus released.

Exploration of a penetrating cerebral wound

The neurological state and the external evidence of injury are highly variable in patients with a penetrating brain injury. For example, a patient with a large open wound and brain tissue visible within it may be fully conscious with no apparent neurological deficit. Conversely, a deeply unconscious patient who has sustained a cerebral gunshot wound may have an insignificant entry wound, which is missed at initial assessment. All penetrating wounds of the brain require urgent, skilled surgical attention. Exploration of an overlying wound should be avoided before definitive surgery. The wound is covered with a sterile dressing and the patient transferred to a neurosurgical unit if one is available. The initial resuscitation and assessment of the injured patient must not be overlooked, as inadequate resuscitation may compound the cerebral insult. In addition, other injuries may need more urgent attention than the cerebral wound. Exsanguination from a ruptured spleen or ventilatory failure from a traumatic pneumothorax can occur during transfer to a neurosurgical centre.

Most penetrating cerebral wounds occur during wars and major civilian unrest.[2,3] When associated with breakdown of medical evacuation facilities, this presents extreme challenges if the general surgeon has no access to neurosurgical help. Surgery should be undertaken as soon as is practical, as delay increases the risk of infection. Prophylactic antibiotic and anticonvulsant therapy should be started. The surgical aim is to remove all devitalised cerebral tissue, extravasated blood, bone fragments and any accessible foreign bodies, and to stop all haemorrhage.[4] Complete debridement of this nature is dependent on adequate exposure and good visibility.

OPERATIVE PROCEDURE

General anaesthesia with airway protection is recommended. The scalp should be shaved. A scalp flap will often afford better access to the area of injury than a simple extension of the external wound. An associated depressed fracture can be elevated through a burr hole a short distance (1–2 cm) from the fracture. The burr hole must not be over or immediately adjacent to the fracture as this increases the risk of intracranial penetration (see Figure 9.6). Great care is still necessary as elevating a fracture by leverage from a burr hole can be hazardous, especially if there is a dural tear. Often it is safer, using a bone rongeur and working from the burr hole, to nibble away the bridge of stable bone between the burr hole and the displaced fragments remaining attached to the surrounding bone. This in turn is nibbled away with the bone rongeur, thus converting the depressed fracture into a free fragment, which can be lifted more safely. When there is an extensive comminuted fracture with loose fragments, good intracranial access may be obtained by lifting these fragments out. Larger fragments should be cleaned and replaced at the end of surgery. A small entry wound through the cranium can be enlarged with rongeur forceps, but access to the underlying brain will still be limited, and here a craniotomy is usually preferable.

The dura can be intact even with a severely depressed fracture. However, it may have been pushed in by bony spicules and stripped from the underside of the adjacent bone with associated extradural venous bleeding. This bleeding is best controlled by one or more hitch stitches, usually of absorbable material, between the dura and periosteum to pull the dura up against the bone, thus compressing the injured vessel (Figure 9.11). Small dural lacerations and contusion or

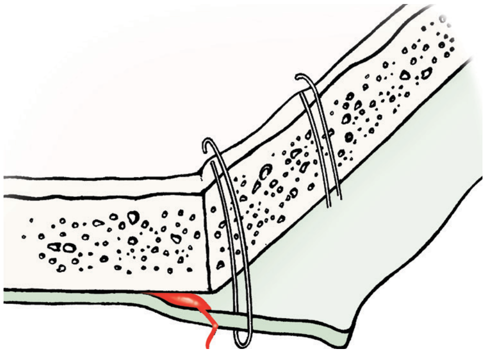

Figure 9.11 *Hitch stitches between the dura and the periosteum.*

lacerations of the underlying cortex can be ignored if there is no significant bleeding or evidence of in-driven bone, hair or other contamination. When access beneath the dura is required and the dura is not already extensively disrupted by the injury, the dura is opened with a U-shaped or cruciate incision and the dural flap(s) turned back to expose the cerebral cortex. The base of a dural flap should be towards the nearest venous sinus to reduce the risk of major venous bleeding (see Figure 9.9).

Bleeding from a tear into a venous sinus can be extremely difficult to control. The operating table should be tilted to raise the patient's head and reduce the venous bleeding, but not so much that bleeding stops and air enters the venous sinus, with resultant risk of major air embolus. An old technique that may still be of value in difficult circumstances is the use of a temporalis muscle graft, which is hammered out into a thin sheet. This can be laid against a bleeding surface to which it adheres, and it is held in position with digital pressure for several minutes. Gelatin sponge or a similar preparation is also effective. Alternatively, pieces of muscle or gelatin sponge, which partly plug and buttress a sinus tear, may be held against the sinus by overlying stitches (e.g. of Vicryl™ 3/0) passed through the dura adjacent to one side of the sinus and through dura adjacent to the other side of the sinus. A sinus tear may be stitched directly, but sutures can tear easily through the thin sinus wall.

Damaged cerebral tissue can be removed by irrigation and suction. A gentle jet of warm saline from a syringe and weak suction (25–35 cmHg) through a fine-bore nozzle (3-mm lumen) will remove all devitalised brain matter and blood clot, but leave healthy brain tissue undisturbed. Any fragments of in-driven bone that become visible are gently extracted with forceps. The utmost gentleness must be observed as brain tissue is very delicate and, with rough handling, the surgeon is in danger of increasing the original injury. Meticulous attention must be paid to haemostasis. Bleeding vessels are coagulated with diathermy. They should be accurately held in fine forceps and the smallest effective current used to minimise damage to the underlying brain (Figure 9.12). Bipolar diathermy is much safer than monopolar diathermy in this situation.

The exploration of *gunshot injuries* is particularly difficult. The entry wound is often small and may be mistaken for a simple scalp wound. The inner skull table is invariably fractured more extensively than the outer table. Therefore, a craniotomy usually gives better access than simple enlargement of the cranial defect, especially as indrawn bone fragments are usually present. Access to the whole track is not possible without causing further damage, and a bullet in the depths of the brain should be left *in situ*. In through-and-through missile injuries the exit wound, which is usually larger and more impressive than the entry wound, should also be explored. The cavitation effect within the brain from any high-velocity bullet makes survival unlikely (see Chapter 4).

After completion of the debridement and replacement of the dural flap(s), the dura is closed with fine absorbable sutures. When brain tissue is swollen or there is a dural defect, it will not be possible to close the dura. Small tears can simply be covered with Gelfoam®, but larger defects should have a transplant graft of pericranium or fascia lata stitched into place. If the patient's condition does not permit this, a large sheet of Gelfoam® or Surgicel® is applied over the surface of the brain and dural repair deferred for a later operation.

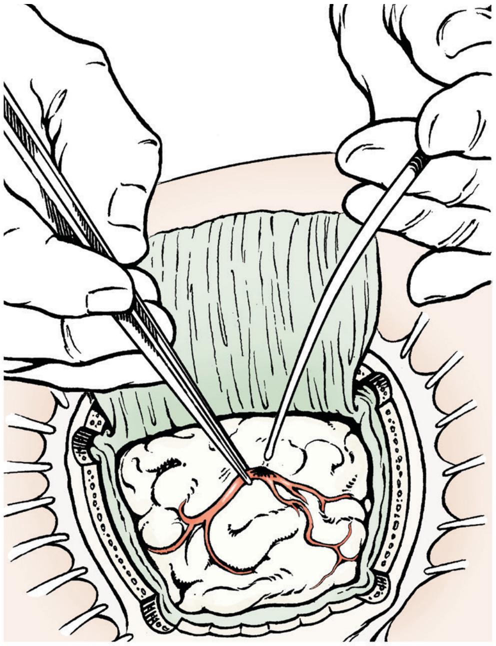

Figure 9.12 *Extreme gentleness is essential on the surface of the brain. Only weak suction should be employed. Any vessel to be coagulated with diathermy must be held accurately and no more current used than is necessary.*

PATHOLOGY AND MANAGEMENT OF BRAIN INJURY

A post-traumatic haematoma, if unrecognised and untreated, can be fatal. For this reason many patients, even with apparently minor head injuries, are detained in hospital for observation. The main purpose of the observation is early detection of this potentially remediable complication. A thorough initial clinical assessment and monitoring of any changes in neurological status are pivotal in detecting a deteriorating situation.[5–8] Causes of any clinical deterioration must be sought and the reasons, other than intracranial bleeds, must not be overlooked. Intracranial causes of neurological deterioration can be confirmed or excluded by a CT scan before transfer to a neurosurgical centre.

The general surgeon may also have under his or her care patients who do not require transfer for neurosurgical intervention, but who have a significant brain injury. Many patients die or suffer long-term sequelae following head injuries in which there is no significant intracranial bleeding.

Although no surgical intervention can alter the prognosis, the general medical care of these patients can be crucial to their outcome.[9–13] This huge subject is outwith the scope of an operative surgical textbook, but a brief synopsis of the pathology of brain injury may be helpful.

Pathology of primary injury

The initial injury causes brain tissue to suffer direct contusional damage or momentary stretching or distortion. In an acceleration–deceleration injury, there may be no external evidence of trauma, but the brain, which is mobile within the cranium, impacts on the bone. The same mechanism, of mobile brain impacting on the skull, explains the contrecoup injury diametrically opposite the area of an impact. In addition, shearing forces tear the brain substance. No healing of disrupted neural cells within the CNS is possible, and the surgeon can do nothing to repair tears within the brain. An initial stage of neural shock, which lasts from a few minutes to a few days, resolves. Further neurological recovery involves the recruitment of other neural pathways and is not due to the 'healing' of brain cells that have been damaged irreversibly.

Pathology of secondary injury

Several factors are responsible for delayed (secondary) brain injury, but the final pathway is mainly that of hypoxia,[9] to which brain cells are the most vulnerable tissue in the body. *Oxygen delivery is dependent on good perfusion by well-oxygenated blood.* Poorly oxygenated blood is often circulating after major trauma. The unconscious patient may have a partially obstructed airway and an inadequate respiratory effort, which can be further compromised by a concomitant chest injury. Brain perfusion, which is dependent on the *cerebral perfusion pressure*, may be poor in the patient with a head injury:

Cerebral perfusion pressure = Mean arterial pressure – Intracranial pressure

This relationship explains why it is extremely important to avoid hypotension in any patient with a head injury, especially as many will already have some increase in intracranial pressure. The commonest cause of hypotension in a patient with a head injury is hypovolaemic shock, usually attributable to co-existent multiple injuries.

CEREBRAL OEDEMA

Cerebral oedema after trauma is from the swelling of injured brain. Initially, a reduction in the volume of CSF allows an increase in cerebral volume without a significant rise in intracranial pressure, but the margin for compensation is small. Thereafter, intracranial pressure rises, with a resultant fall in cerebral perfusion. When this causes brain ischaemia there is an additional hypoxic insult to the brain, causing more cerebral oedema, and a deteriorating vicious circle is established. Hypercapnia dilates the cerebral blood vessels, causing a rise in intracerebral pressure, and must be avoided. Intracranial pressure can also be increased by obstruction of venous drainage, whether by the struggling of a confused patient, by the adoption of a head-down position or by marked turning or twisting of the head to the side.

INTRACRANIAL HAEMORRHAGE

Extravasated blood occupies space within the closed intracranial compartment, thus increasing intracranial pressure and reducing cerebral perfusion. Haematomas also displace the brain and cause localised pressure.

Extradural haematoma

A meningeal artery, which runs in close apposition to the inner surface of the skull, can be torn when the skull is fractured and the artery bleeds into the extradural space. The middle meningeal artery, under the relatively thin temporal bone, is the most vulnerable. Fractures in this area may occur from a relatively minor direct blow to the head, often with little primary brain injury. Classically, there has been only an initial transient loss of consciousness, a fracture that crosses the skull marking of the middle meningeal artery and the patient has been kept in hospital for observation. A few hours later, as the severed artery continues to bleed and the haematoma increases in size, the intracranial pressure starts to rise steeply. Cerebral perfusion worsens and the level of consciousness deteriorates. Displacement of the brain by the haematoma causes impaction on the tentorial opening. This first produces localising signs, which include a third-nerve palsy, usually with a dilated pupil, on the side of the haemorrhage. Terminally, both pupils become dilated and fixed and decerebrate rigidity develops. Unfortunately, the classical early signs are the exception rather than the rule, and localising signs can be misleading. However, the haematoma is usually on the side of the first pupil to dilate and/or become fixed.

Acute subdural haematoma

Cerebral veins can be torn as they cross the subdural space to the venous sinuses by any shearing or deceleration force that temporarily distorts the intracranial anatomy. Such bleeding may be immediate and massive, especially if the tear extends into a venous sinus, and only specialist surgery can offer any realistic hope of success. A more minor injury may result in a haematoma that collects in the few hours after an injury and may present clinically like an extradural haematoma. Unlike extradural haematomas, acute subdural haematomas more often occur in association with primary brain damage that is more major than the haematoma and intracranially may be remote from the point of impact. Most areas of severe brain contusion will be overlain by small subdural haematomas of limited significance.

Chronic subdural haematoma

Chronic subdural haematoma occurs classically in an elderly patient who presents, some weeks after an apparently minor head injury, with altered consciousness, headaches and/or new neurological signs. There is some cortical shrinkage in old age, and the brain can move more freely within the cranium. A shearing force is thus more likely to tear a vein and cause a subdural bleed. In the elderly a fairly large haematoma can collect without any increase in pressure, as it is compensated for by a reduction in the larger volume of CSF that is associated with the ageing brain. When the haematoma liquefies it may expand significantly, so that compensation is no longer possible and neurological deterioration occurs.

Intracerebral haematoma

Tears of the brain substance may result in haemorrhage deep within the cerebral cortex, a situation that is unlikely to be amenable to a generalist's intervention. A surface laceration may produce haemorrhage into the ventricular system or into the subarachnoid space.

General care of the patient with a head injury

A secure airway, adequate gas exchange and full resuscitation are vital in maintaining oxygen delivery to the cerebral cortex and preventing secondary brain injury. Sedation and mechanical ventilation are often necessary in order to obtain a CT scan in a patient with impaired consciousness. Mechanical ventilation is then often continued, because in addition to securing the airway and optimum ventilation, it also provides additional opportunities for maximising cerebral perfusion.[10,11] Various agents to reduce brain swelling – including mannitol, diuretics and steroids – have been tried over the years. On the whole they have been disappointing, except as a temporary holding measure during transfer to a neurosurgical department or to an operating theatre for definitive treatment of a remediable cause of increased intracranial pressure. Steroids have finally been shown in a major trial to be of no benefit after head injury.[12] Antibiotic prophylaxis is usually given to patients with compound skull fractures. Any patient with a penetrating brain injury, an intracerebral haematoma or a compound depressed skull fracture is at risk of post-traumatic epilepsy. To prevent epileptic attacks these patients are usually given anticonvulsant treatment,[13] for example, phenytoin given at a loading dose of 15–20 mg/kg, followed by maintenance at 5 mg/kg per day.

DETERIORATION

When monitoring detects neurological deterioration, all remediable causes must be explored. Hypoxia, hypovolaemic shock, oversedation and a post-traumatic convulsion should all be considered, in addition to an intracranial space-occupying haematoma. It must be remembered that generalised or localised brain oedema can also cause increased intracranial pressure, deterioration in level of consciousness and even new focal neurological signs. Increased pressure from a space-occupying haematoma is obviously amenable to surgical evacuation, whereas cerebral oedema is not. There has, however, been recent renewed interest in the old technique of removing part of the skull to relieve the pressure on the swollen brain. However, trials are reporting disappointing results.[14,15]

In patients in whom deterioration has been shown by CT scan to be due to an intracranial haematoma, urgent transfer to a neurosurgical unit is arranged. The general surgeon working in a remote area of the developed world may have to operate occasionally for a suspected extradural haematoma in a patient who cannot be evacuated to a neurosurgical unit, but the surgeon will almost certainly have the telephone support of a neurosurgical colleague. Additionally, CT scanning may have been possible so that not only has a haematoma been confirmed, but it is known whether it is small and incidental or the main cause of the increased intracranial pressure. Also, a CT scan will show in which tissue plane and under which area of cranium the haematoma has formed. Ultrasound can show deviation of the midline and, in the absence of CT scans, may help determine on which side the space-occupying haematoma has formed.

A surgeon with no access to imaging has to rely on a clinical diagnosis,[16] and exploration may have to be through multiple burr holes. Surgery may prove fruitless, but as surgical evacuation of the haematoma is the only effective treatment for the life-threatening rise in intracranial pressure associated with an intracranial space-occupying haematoma, the attempt is justified.

EXPLORATION AND EVACUATION OF INTRACRANIAL HAEMATOMAS

Once a decision has been taken to operate, the patient should be given mannitol. A 20 per cent solution of mannitol is given intravenously over 5 minutes at a dose of 0.5 mg/kg. Intracranial pressure will fall temporarily and although repeat doses can be given, they become progressively less effective. Antiseizure prophylaxis with phenytoin should be commenced and the patient is ventilated to maintain a low P_aCO_2 (ideally 4–4.5 kPa). On transfer to the operating theatre, the patient is placed at a 20 degree head-up tilt to improve venous drainage, and the whole head shaved and prepared for surgery.

Emergency burr holes in trauma

A surgeon who has the benefit of prior imaging will plan to make a single exploration through the skull overlying the haematoma, and will know whether blood will be encountered in the extradural or subdural space.

Urgent exploration, without the benefit of a scan, is best performed near the site of the fracture or where there is external evidence of trauma.[1] If there is no sign of external trauma, the thin temporal region, with the underlying middle meningeal artery, is the most likely site of an extradural haemorrhage. Although the operation can be performed under local anaesthesia – or with no anaesthesia in an unconscious patient – a general anaesthetic with endotracheal intubation to control the airway and ensure adequate ventilation is recommended. If there is a significant extradural haematoma, it will present at the burr hole under pressure.

TREATMENT OF AN EXTRADURAL HAEMATOMA

An extradural haematoma needs to be fully evacuated and the bleeding vessel secured. Access must be increased by enlarging the burr hole in the direction indicated by the situation of the clot, usually towards the skull base. Alternatively, a formal craniotomy may be preferable. An actively bleeding vessel cannot be identified if there is overlying clot or fresh bleeding obscuring the view. A technique of irrigation and suction, similar to that employed for penetrating cerebral wounds and described above, is helpful. Ideally, the artery is identified and coagulated or ligated. If the middle meningeal artery is ruptured at the base of the skull, access may not be possible and a plug of bone wax pushed into the foramen spinosum will provide the necessary pressure to arrest the haemorrhage. Frequently, the site of the haemorrhage is obscure and active bleeding has ceased. After evacuation of the clot and the arrest of any active bleeding, simple closure with an extradural vacuum drain is sufficient. Persistent venous extradural haemorrhage may occur from areas where the dura has been stripped from the bone by the expanding arterial haematoma. The bleeding is controlled by application of Gelfoam® and dural hitch stitches to compress the damaged veins (see Figure 9.11).

TREATMENT OF AN ACUTE SUBDURAL HAEMATOMA

Unfortunately, the surgeon who has had to rely solely on clinical judgement may be faced with no extradural haematoma under the first burr hole. A subdural collection should then be suspected, especially if the dura is bulging and plum-coloured. The bulging dura is opened through a cruciate incision, which allow evacuation of the clot. Gentle lavage and suction allow inspection of vessels on the brain surface, and any bleeding vessel is coagulated with diathermy. The burr hole can be enlarged if bleeding is continuing but the vessel has not been exposed. An acute subdural haematoma is often associated with a large area of underlying trauma to the brain, which can only be exposed by a craniotomy. The control of haemorrhage from dural veins and venous sinuses is described above (Exploration of a penetrating cerebral wound).

MULTIPLE BURR HOLE EXPLORATION

Even if an extradural clot is discovered, there may be a contralateral subdural haematoma on the opposite side. When subdural clot is obtained, further collections may be present at other sites. When no significant extra- or subdural clot is found at the initial burr hole, the underlying pathology is most frequently oedema from brain contusion, but there is also the possibility of extradural or subdural haematomas at other locations. A difficult decision must thus be made, in the absence of imaging, as to whether to explore through additional contralateral or ipsilateral burr holes.[4] Additional frontal and parietal burr holes should be positioned so that they can be joined to form a satisfactory bone flap for a subsequent craniotomy if this proves necessary (Figure 9.13).

Burr holes for chronic subdural haematoma

The haematoma can be drained through a burr hole and, as all haemorrhage will have long since ceased, extended access to the underlying cortex is not required. The standard four burr hole exploratory approach, if imaging is unavailable, is shown in Figure 9.14. It must be remembered that these collections may be multifocal and the discovery of a haematoma in one area does not exclude a second collection elsewhere.

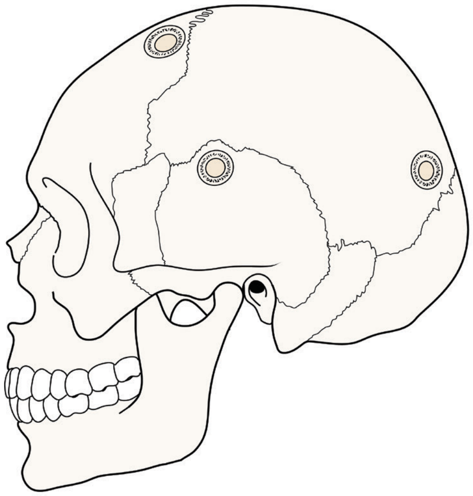

Figure 9.13 *When an initial temporal burr hole has not released clot, additional frontal and parietal burr holes may be successful.*

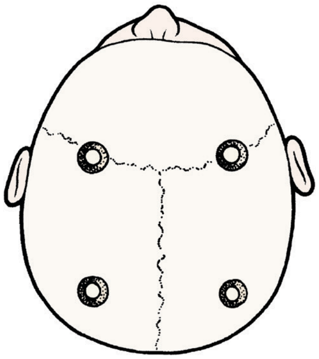

Figure 9.14 *Exploratory bilateral burr holes for a suspected chronic subdural haematoma.*

SPINAL CORD SURGERY

Spinal cord decompression

Elective surgery on the spinal cord and the vertebral column is the province of the neurosurgeon and the orthopaedic surgeon. Emergency surgery is indicated for clinically severe cord compression whether this is due to a haematoma, pus, a secondary deposit or a central disc prolapse. For most general surgeons, their responsibility for patients with these conditions is limited to recognition of the pathology, and its confirmation, followed by urgent referral to the relevant specialist. Isolated generalists may on occasion have to operate themselves, and often without confirmatory imaging. There are several surgical approaches for decompression and the choice is dependent on the underlying pathology and the circumstances in which the surgeon is operating.

Tuberculosis of the spine may cause local compression from a mixture of pus, necrotic debris and bony sequestra. Paraplegia is usually of insidious onset and fluctuant severity, and minor neurological symptoms may settle on antituberculous chemotherapy alone. Despite this, in some areas of the world, surgical decompression of a cord threatened by tuberculosis is still a common operation. However, it should be performed, if at all possible, by surgeons who have had adequate training and experience in orthopaedic surgery or neurosurgery. Unlike surgery for an acute central disc prolapse threatening the spinal cord, surgery for tuberculosis is rarely a matter of great urgency. The disease process is located anteriorly, affecting an intervertebral disc and the adjacent two vertebral bodies, and therefore cannot be decompressed satisfactorily from the posterior approach.

POSTERIOR APPROACH

Emergency surgery via a posterior approach may be performed to drain pus caused by pyogenic organisms or a haematoma compressing the cord.[17] It is also a suitable approach for certain intervertebral disc lesions such as a large central disc prolapse compressing the cauda equina.

Surgery begins with a vertical incision over the spinous processes. The muscles are then stripped off the spines and laminae, and retracted laterally. *Fenestration*, in which a window is created into the spinal canal through the ligamentum flavum between two adjacent vertebral arches, should be sufficient to drain pus or blood in the epidural space and decompress the spinal cord. It is also possible very gently to retract the nerve root medially to approach a lateral disc prolapse (Figure 9.15). However, the inexperienced spinal surgeon forced to operate on a prolapsed disc will almost certainly benefit from the safer, more extensive, access afforded by a *laminectomy*. Laminae are excised with bone nibblers, and care must be taken to avoid damage to spinal cord or nerve roots. Unfortunately, the more extensive the laminectomy the greater the risk of late instability of the spine. This is especially so if the anterior part of the spinal column – that is, the vertebral bodies and discs at the level of a laminectomy – is affected by disease impairing its stability.

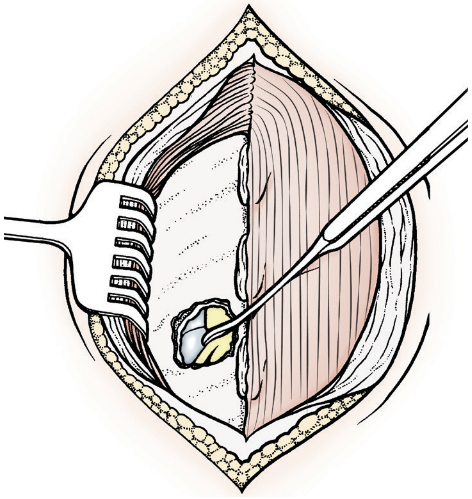

Figure 9.15 *The ligamentum flavum between two adjacent laminae has been fenestrated. The dural tube (theca) and the nerve root stretched over a disc protrusion may be retracted to expose it.*

ANTERIOR APPROACH

An anterior approach provides access to pathology of the vertebral bodies and discs compressing the cord from the front. It is a good approach for the anterior cord decompression required in tuberculosis. The excision of the necrotic vertebral body and disc is then followed by a cortical bone graft from the iliac crest to restore spinal stability and correct the angulation deformity of vertebral body collapse. In the neck, the approach is between the thyroid gland and the carotid sheath (see Chapter 10, p. 186). In the abdomen, the bodies of the lumbar vertebrae can be approached via a muscle-cutting loin incision and an extraperitoneal dissection. In the thoracic spine, however, this approach necessitates a thoracotomy[17], which will not be a viable option in a remote rural hospital with limited anaesthetic facilities. It is in such hospitals that general surgeons may find themselves forced to operate on patients with a worsening tuberculous paraplegia, and a costotransversectomy is a safer compromise.[18]

COSTOTRANSVERSECTOMY

This procedure allows the surgeon to decompress anterior pathology in the thoracic spine from a posterior approach. It avoids the necessity of opening the chest and is performed through a vertical or curved incision a few centimetres from the midline. The incision is deepened to expose the transverse process of the vertebra and the posterior end of the rib, which are then resected (Figure 9.16). This will often result in entry into a paraspinal abscess. This abscess is in free communication, through a necrotic area of the vertebral body or

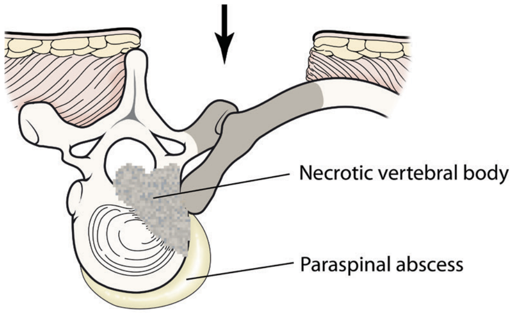

Figure 9.16 *Spinal tuberculosis is primarily an anterior disease. In a costotransversectomy via a posterolateral approach, the initial bony excision of the costotransverse joint affords entry into the paraspinal abscess compressing the cord through the necrotic area of a vertebral body or disc. The shaded area represents the bone that will have to be removed.*

the intervertebral disc, with the abscess that is compressing the cord. If, however, pus is not initially encountered, the anterior spinal canal abscess must then be entered through the infected and softened disc or vertebral body.

Myelomeningocoele

Myelomeningocoele is a congenital abnormality that is associated with severe neurological deficit below the lesion, often with musculoskeletal abnormalities. Urological complications are almost inevitable. In addition, many infants will develop progressive hydrocephalus requiring ventricular shunting, and associated learning difficulties are common. Survivors will require long-term medical and social support. If no surgery is undertaken to cover the exposed neural tissue of the spinal cord, most infants develop infection and succumb within a few weeks. Therefore, the advisability of any surgical intervention should be carefully considered, especially where the availability of long-term medical care is minimal.

If surgery is planned, it can be carried out within a few days of birth, and on occasion can even be performed under local anaesthesia.[17] A skin incision is made round the exposed meninges, or round the neural plaque if the meningeal sac has already ruptured, and the plane developed between the skin and the dura until the neck of the sac is reached. The dura is then incised close to the neck but leaving sufficient dura to close it over the neural plaque. Any neural tissue entering the sac is dissected free and preserved, and the dura is closed. Primary skin closure may be possible or flaps may have to be mobilised.

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10

SURGERY OF THE NECK

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GENERAL TECHNIQUE

ANAESTHESIA AND PREPARATION

Local infiltrative anaesthesia is suitable for superficial surgery in the neck. General anaesthesia with a laryngeal mask is appropriate for most procedures but longer operations or procedures requiring movement of the head are safer performed with endotrachael intubation. Cervical plexus blocks have proved to be both a safe and effective alternative to general anaesthesia for carotid endarterectomy.

The positioning of sterile towels so that they do not slip during surgery is important. A well-established method is illustrated in Figure 10.1. The patient's head may then be turned to either side or held straight with the occiput resting within a ring or horseshoe support. Extension of the neck is achieved with a sandbag beneath the shoulders, and supraclavicular access is improved by traction on the arm.

Even relatively superficial neck surgery can result in troublesome haemorrhage from anterior jugular veins and their tributaries. A steep head-up tilt will reduce venous bleeding, but at the risk of air embolus from negative intravenous pressure. Any hole in a large vein must be immediately occluded by digital pressure and the anaesthetist warned of the possibility of entry of air into the circulation.

NECK INCISIONS

Wounds in the neck can heal with disfiguring scars. Incisions must be planned, wherever possible, to follow the natural skin creases (or relaxed skin tension lines). These run approximately horizontally, and most incisions can be placed along them (Figure 10.2). When extensive longitudinal access is required a vertical incision can often be avoided by making two separate transverse incisions (see Figure 10.8b), and this is particularly important anteriorly, where vertical scars will hypertrophy and contract. Even a horizontal incision anteriorly will hypertrophy in the suprasternal notch, and incisions for thyroid surgery should not be positioned too low for this reason.

If a vertical component to an incision is inevitable, it will cause less scarring if placed laterally either along the anterior border of sternocleidomastoid (see Figure 10.4b) or along the anterior border of trapezius.

Postoperatively, a deep haematoma can threaten the airway from compression. Vacuum drainage for 24–48 hours is favoured by many, but it is not a substitute for meticulous haemostasis. A superficial haematoma must also be avoided as it can increase subcutaneous fibrosis and scarring. Accurate apposition of skin and platysma is important for a good cosmetic result. Platysma is sutured with absorbable sutures, and provides considerable support to the skin closure. Clips or interrupted skin sutures can therefore usually be removed from the transverse anterior wounds used for thyroid surgery within 48 hours, without fear of wound dehiscence, although sutures in other neck wounds should normally be left for around 7 days.

TRAUMA

Closed trauma to the neck is dominated by forced flexion or extension injuries to the cervical spine and spinal cord (see Chapter 5). Mechanical protection of the cervical spine is essential until an unstable cervical fracture has been excluded. An intimal tear of a carotid artery can occasionally be caused by the same force. No neurological symptoms or signs should be dismissed and preoperative arterial imaging should be considered in a stable but unconscious patient before exploration of non-vascular injuries. An anterior impact or crushing injury to the neck may inflict severe bruising and swelling,

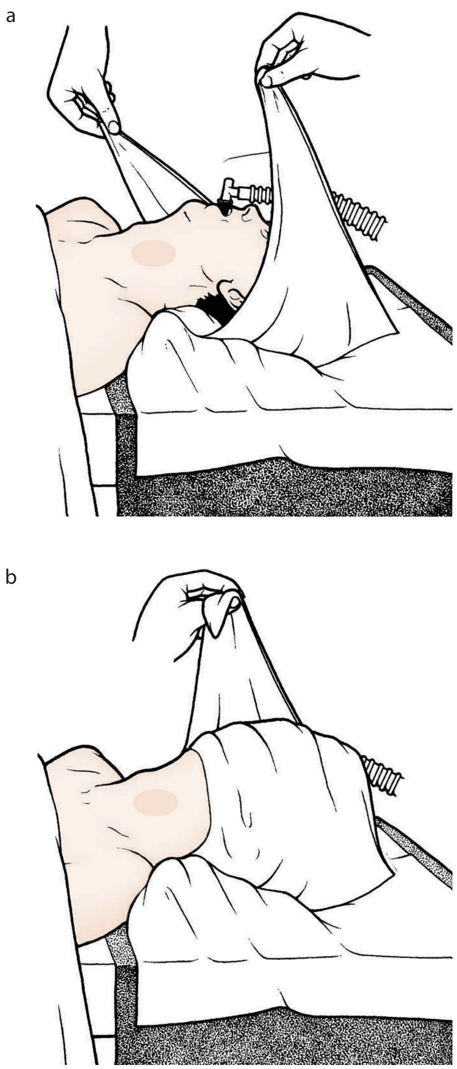

Figure 10.1 *(a) The patient's head is lifted. A sterile waterproof paper sheet and two sterile towels are laid beneath the head and neck. (b) The uppermost towel is folded across, over the chin, to cover the face and the anaesthetic tube.*

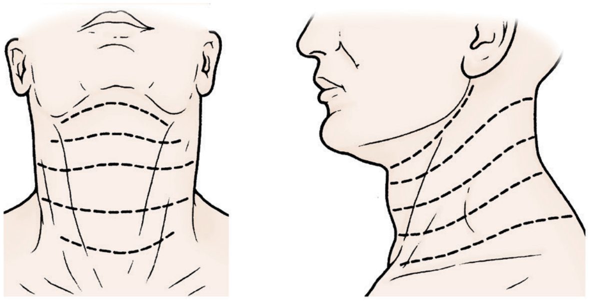

Figure 10.2 *Relaxed skin tension lines in the neck are approximately horizontal.*

with progressive obstruction of the airway. Less commonly, a fracture is sustained to the skeleton of the larynx, or the trachea is transected.

Penetrating and open trauma includes a wide range of injuries, from clean knife wounds to the extensive soft tissue damage seen in military conflict.[1] Stab injuries are common where there is a high incidence of urban violence. Guns are increasingly replacing knives and in some areas are the most common cause of penetrating neck trauma. In assaults, traffic accidents and in falls from a great height, penetrating and forced flexion–extension injuries can co-exist.

Surgical management of neck trauma

Knowledge of the mechanism of injury is important in the assessment. Even in an open injury, the possibility of an unstable cervical fracture may have to be considered even though mechanical protection of the spine will make assessment of the injury, control of haemorrhage and maintenance of the airway more difficult.

Establishment of a secure airway is the first priority. Endotracheal intubation is essential in any patient with neck trauma who is unconscious or who has respiratory difficulty. The cuffed tube also protects the lower respiratory tract from further inhalation of blood. If endotracheal intubation is not possible, an emergency tracheostomy may be required. A cricothyroidotomy may be a faster alternative in an emergency.

Arrest of haemorrhage is the next priority. External haemorrhage can usually be controlled by direct pressure until a wound is explored. Haemorrhage into the pharynx may be profuse, but once the airway is secure, either with an endotracheal tube or with a tracheotomy, pressure on the bleeding areas with pharyngeal packing will often bring the haemorrhage under control. The soft tissue of the neck is supplied almost entirely from branches of the external carotid artery. On rare occasions, emergency ligation of an external carotid artery may be life saving. Clear confirmation of an intact internal carotid artery is mandatory. The emergency surgical approach is through an incision along the anterior border of sternocleidomastoid. The external carotid is usually the more anterior division and has branches. However, the carotid bifurcation may be distorted by trauma and haematoma. Spasm, particularly in a young patient, means that the calibre of a vessel is no guide to its importance or identity. If a vessel has to be clamped before exploration is complete, it must be done with a view to the possible need for repair or replacement.

If the patient is stable and there is only a small skin wound, both the surgeon and the patient may be understandably reluctant to consider an unnecessary exploration. There is still debate as to whether all penetrating wounds should be explored or whether a more conservative policy is appropriate. Many of the principles of management have been evaluated in South Africa where, with a selective policy, exploration is reserved for those who are judged to be at significant risk of having damaged important structures that require repair. The history of injury, the direction of the track, the patient's symptoms and the physical examination are all important.

Where CT or duplex scanning is widely available, many consider it is obligatory to image the vessels when a penetrating lateral neck injury is treated conservatively. The scan should exclude a carotid injury that may not be immediately apparent clinically, such as a pseudoaneurysm or an intimal flap with related intraluminal thrombus.

Vascular injuries

The neck is divided into three zones for the management of trauma in relationship to possible vascular injury (Figure 10.3). Wounds in Zone I may have involved the major vessels in the superior mediastinum, and any exploration of such a wound will almost certainly require simultaneous access to the neck and mediastinum, with a supraclavicular incision extended down as a median sternotomy (Figure 10.4a). A widened mediastinum on chest X-ray will alert the surgeon to a severe injury and an angiogram should be performed before exploration unless haemorrhage forces immediate surgery. If at all possible, surgery should be undertaken by an experienced vascular or cardiothoracic surgeon (see also Chapters 6 and 8). The potential help from the interventional radiologist should be remembered, as placement of a balloon into one of the major arch vessels may be sufficient to control haemorrhage and allow direct surgical repair.

Stab and bullet wounds are most commonly situated in Zone 2 and the risk of major vascular damage is higher for lateral wounds. Some surgeons recommend exploration for all laterally placed Zone 2 injuries. If a selective policy is followed, exploration should be undertaken of any lateral wound with evidence of significant haemorrhage. Preoperative angiography is not routinely recommended in an unstable or actively bleeding patient. Good access is essential, and an oblique vertical incision along the anterior border of sternocleidomastoid will provide the best arterial and venous exposure (Figure 10.4b).

A clean incision into a carotid artery can be sutured, but more frequently a vein patch is more appropriate to prevent stenosis (see Chapter 6). Consideration should be given to a temporary intraluminal shunt to preserve cerebral perfusion, and if the internal carotid is injured, this is essential. Stroke is a significant possibility even in a young patient with no other arterial disease. A common carotid injury, which can be isolated with clamps below the bifurcation, does not always require a shunt as retrograde external carotid flow will perfuse the intracranial carotid territory. An injured internal jugular vein can be ligated without adverse effect if the contralateral internal jugular is patent.

Penetrating wounds in Zone 3 are directly over the internal carotid artery. Access is difficult and simultaneous access

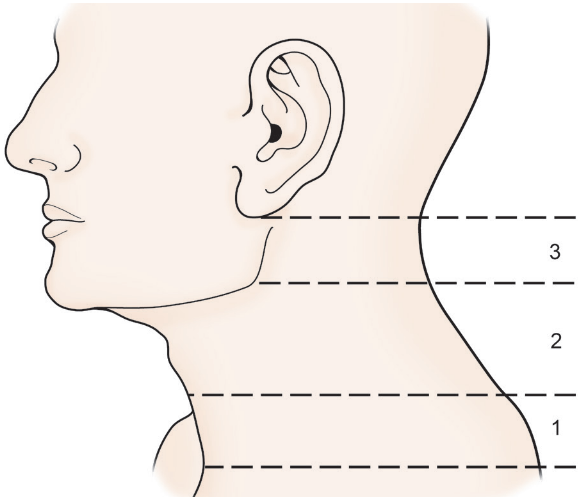

Figure 10.3 *Zone 1 extends for 1 cm above the upper border of the manubrium; Zone 3 is above the angle of the mandible; Zone 2 lies in between.*

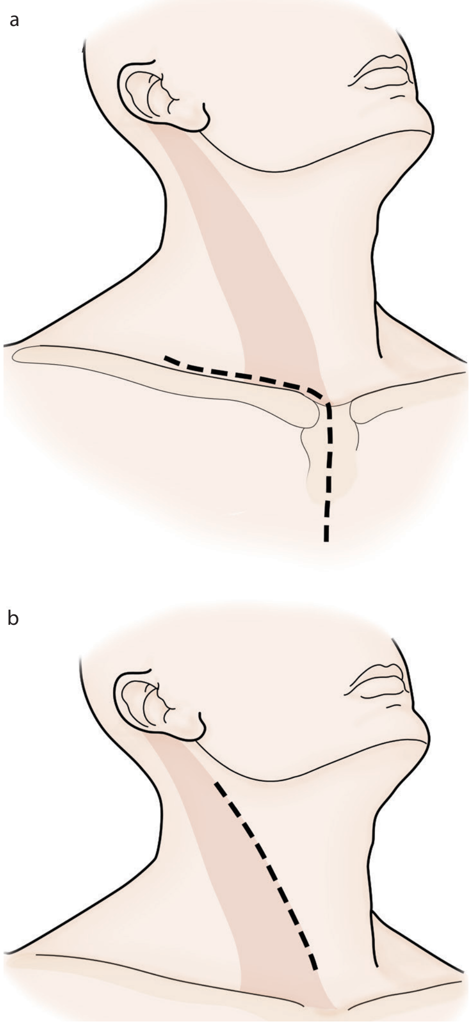

Figure 10.4 *(a) Zone 1 injuries to the carotid artery may require simultaneous access to the superior mediastinum. A median sternotomy incision can be extended as a supraclavicular incision or as an incision along the anterior border of sternocleidomastoid. (b) The incision along the anterior border of sternocleidomastoid gives the best access to the carotid artery in an emergency.*

intracranially may be necessary. A preoperative angiogram, together with the involvement of a vascular specialist and, occasionally, also a neurosurgical specialist, is important. Venous injuries in particular may extend up to the base of the skull. Venous bleeding will be torrential as the vessel is held open at the jugular foramen. If a Fogarty catheter is inserted into the foramen, the inflated balloon can control haemorrhage while a purse-string suture is inserted.

Laryngeal, tracheal and oesophageal injuries

Blunt trauma, with resultant haematoma and oedema, may obstruct the airway, and in a severe crushing injury there may be fractures of the skeleton of the larynx. Blunt trauma can usually be treated conservatively and any threat to the airway managed by tracheotomy. Laryngeal injury is best assessed on CT scanning. A fractured hyoid is usually managed conservatively, but a thyroid cartilage fracture with displacement often requires repair with wires or mini-plates. A history of anterior impact associated with emphysema requires bronchoscopy to exclude a transected trachea, as sudden asphyxia can occur if the divided ends become displaced. Formal repair is indicated for this injury.

Penetrating injuries will often heal spontaneously. A selective policy for exploration has generally been adopted since it was shown to be safe to explore only wounds through which air was bubbling or those that were associated with major haemoptysis or haematemesis.[2] All other patients with emphysema, and patients where there is another reason to suspect injury, are managed conservatively with prophylactic antibiotics and a nil-by-mouth policy until a contrast study has excluded an oesophageal leak. If a leak is demonstrated, oral intake must await a repeat contrast study to show that the leak has sealed. Further assessment of a tracheal injury includes laryngoscopy and bronchoscopy.

When repair is indicated, access to the superficial larynx and trachea is relatively straightforward. Simple closure, after wound toilet, with interrupted absorbable sutures is generally satisfactory. Access to the deeply placed pharynx and cervical oesophagus is difficult, especially when the anatomy is distorted with haematoma formation. The approaches described below for drainage of retropharyngeal and parapharyngeal abscesses can be used, but a surgeon with limited experience in the neck will be reluctant to attempt any formal repair. Fortunately, arrest of haemorrhage, drainage of the parapharyngeal space and a strict nil-by-mouth policy until the breach has healed will often suffice.

Nerve injuries

Any penetrating injury to the neck may sever a nerve. Optimum operative conditions and surgical skill are more important than timing in repair, and referral to the relevant specialist is important (see Chapter 4).

INFECTIONS

Cellulitis in the neck requires prompt treatment with antibiotics. Careful monitoring of the airway is important as a tracheotomy may occasionally become necessary. Any abscess should be drained. The underlying pathology must be sought as this may require surgical attention. Contamination from a breach in the wall of the hypopharynx or the cervical oesophagus should be suspected in any patient who has had recent cervical trauma or surgery.

Abscesses can occur in any of the fascial spaces in the neck. The infection may be a direct extension of a primary infective process or secondary to a suppurative lymphadenitis in the drainage nodes. *A peritonsillar abscess* (quinsy), the combined *submental and submandibular abscess* (Ludwig's angina) and pyogenic *retropharyngeal abscesses* present intraorally and are considered in Chapter 11.

Retropharyngeal abscess

The retropharyngeal space lies between the pharynx and the posterior layer of the deep fascia, and extends from the base of the skull to the level of the tracheal bifurcation in the posterior mediastinum. In the adult, retropharyngeal abscesses are usually tuberculous, secondary to cervical spine involvement. In contrast to pyogenic retropharyngeal abscesses in the child, which are drained into the oropharynx (see Chapter 11), the tuberculous pus should be drained to the exterior. A horizontal incision is made, one finger breadth below the angle of the jaw. The tail of the parotid gland is dissected from the sternocleidomastoid, which is then retracted. The carotid sheath is retracted posteriorly. The superior constrictor is then identified and, by passing a finger lateral and posterior to the pharynx, the retropharyngeal space can be entered. Locules are broken down, the pus evacuated and a deep drain left in the cavity.

Parapharyngeal abscess

The parapharyngeal space lies lateral to the pharynx. It is bounded laterally by the lateral pterygoid muscle and the parotid gland. It extends from the base of the skull to the level of the hyoid bone, where it is limited by the fascia over the submandibular gland. The carotid sheath lies posteriorly. An abscess in this space may be associated with a tonsillar infection and a quinsy, or with an infected lower third molar tooth. The primary pathology should be addressed first. However, drainage of pus will probably still be inadequate, and direct drainage of the parapharyngeal space may still be required. A horizontal incision is made over the anterior border of sternocleidomastoid, two finger breadths below the jaw. The sternocleidomastoid muscle is retracted posteriorly and the deep cervical fascia incised to enter the abscess cavity (Figure 10.5). This abscess is deep and often multiloculated,

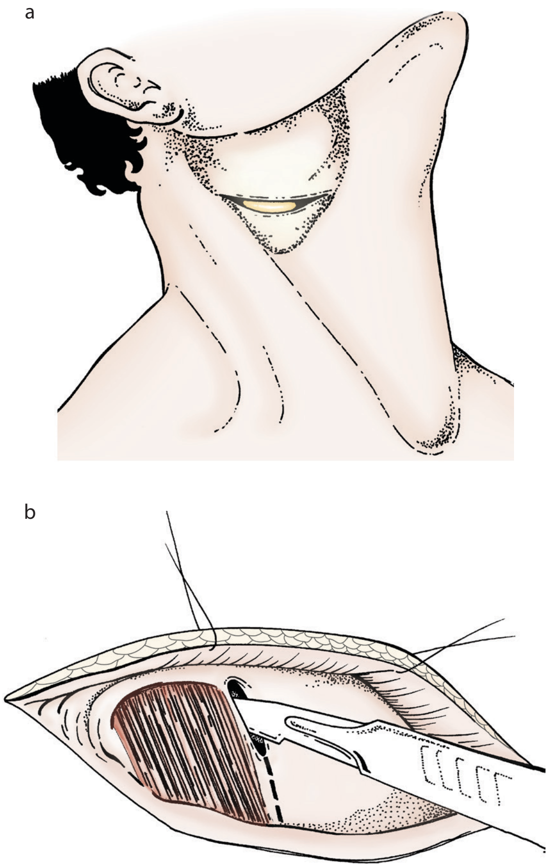

Figure 10.5 *(a) The skin incision for drainage of a parapharyngeal abscess. (b) The deep cervical fascia is incised at the anterior border of sternocleidomastoid and the abscess entered. This approach is also used for access to the deep lymphatic tissue of the neck and for access to the upper oesophagus and hypopharynx.*

and is best explored with blunt finger dissection. It will also require a drain left *in situ* after initial drainage.

Acute mastoiditis

Acute mastoiditis is discussed in Chapter 11.

Acute parotitis

This once common complication in the postoperative surgical patient is now a rarity. It is associated with poor hydration, nutrition and mouth hygiene. In the early stages it may resolve on antibiotic therapy, but once pus has formed it must be drained. A small transverse incision, to minimise any risk to the branches of the facial nerve, is made overlying the area of greatest swelling. It is deepened until pus is encountered. Fortunately, the abscess usually occurs in the superficial portion of the gland and the facial nerve is safe, lying deep to the abscess cavity.

SURGERY OF LYMPH NODES

Surgical anatomy

The lymph nodes of the neck are somewhat arbitrarily divided into groups, which are then described according to the position in which they lie (Figure 10.6):

- *Submental* and *submandibular nodes* drain the floor of the mouth and the tongue. These nodes are described as level I cervical nodes.
- *Deep cervical nodes* lie deep to the sternocleidomastoid muscle and the deep cervical fascia. They lie both outside and within the carotid sheath, in contact with the internal jugular vein. They drain the tonsil, the pharynx, the larynx, the trachea and the thyroid gland. Inflammation within them is therefore common with upper respiratory infections, and carcinoma of the pharynx, larynx or thyroid may present with an enlarged metastatic node in this group. They are subdivided into level II, III and IV cervical nodes, representing the upper, middle and lower nodes of this group.
- *Preauricular*, *mastoid* and *occipital nodes* are superficial nodes that drain the skin and superficial tissue of the face and scalp.
- The *posterior triangle nodes* are deep to the investing fascia. They are classified as level V nodes.
- *Supraclavicular nodes* are continuous with the superior mediastinal nodes and with the axillary nodes. Metastatic involvement is seen in breast, bronchial and upper gastrointestinal cancer. Supraclavicular nodes are also classified as level V cervical nodes.
- *Anterior compartment nodes* surround the midline visceral structures and include the retropharyngeal, paratracheal, prelaryngeal and pretracheal nodes. They are classified as the level VI group.

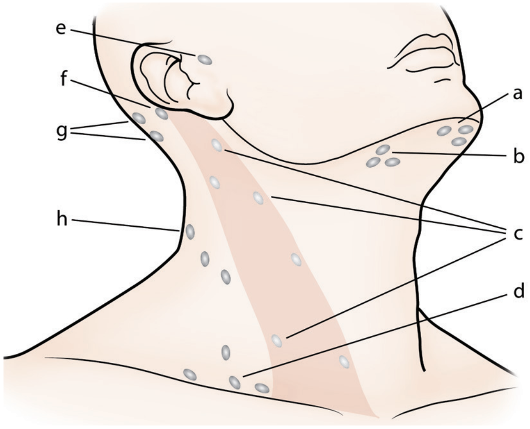

Figure 10.6 *The cervical lymph nodes. a = submental; b = submandibular; c = deep cervical; d = supraclavicular; e = preauricular; f = mastoid; g = occipital; h = posterior triangle.*

Drainage of purulent lymphadenitis

Purulent lymphadenitis can occur secondary to a tonsillitis or other upper respiratory tract infection, and is encountered most frequently in infants. The upper deep cervical chain is the most commonly involved, but by the time it is apparent that there is pus and that the infection will not resolve with antibiotics, there is simply a collection of pus laterally in the neck, which must be drained. A formal dissection with identification of the sternocleidomastoid and incision of the deep fascia to enter the deeper planes is seldom necessary. A small transverse incision over the most prominent part of the swelling, which is then deepened until pus drains, is normally sufficient. This incision will leave a satisfactory scar but will provide inadequate continuing drainage unless a drain is placed into the depth of the abscess and sutured to the skin, as illustrated in Figure 4.7 (p. 48).

Diagnostic lymph node biopsy

The differential diagnosis of an enlarged cervical lymph node includes inflammation, lymphoma and metastatic malignancy. Up to one in five patients with a carcinoma of the nasopharynx, oral cavity, oropharynx, larynx or hypopharynx presents with a nodal metastasis. Such nodes should be excised *en bloc* with the other drainage nodes and the primary malignancy to maximise the chance of cure. Nodal biopsy in isolation for diagnosis should be avoided as there is evidence that this increases morbidity, and possibly decreases long-term survival, in patients with squamous carcinoma. A general surgeon who sees a patient with an isolated neck node, particularly in the submandibular area or in the deep cervical chains, should seek an ENT opinion prior to biopsy, so that malignancy within the drainage area can be excluded. The position of the enlarged node is a guide as to the site of the primary pathology.[3] Thyroid cancer can also present with a cervical node metastasis, but in this cancer an initial excision of the node does not so adversely affect prognosis. Malignant supraclavicular nodes are usually associated with advanced malignancies, often from a primary in the breast, chest or abdomen, which is no longer surgically curable. Isolated excision biopsy is therefore oncologically harmless.

Fine-needle aspiration may be sufficient to confirm metastatic cancer cells, but often cannot differentiate between inflammatory and lymphomatous changes, for which a node biopsy is necessary. The histologist must be able to study the architecture of the gland and, ideally a whole node is excised, with the dissection on the capsule of the node. If this is not possible due to the proximity of vital structures or when nodes are matted together, a generous wedge excision is a safe compromise.

Occipital and *posterior triangle nodes* are relatively superficial with no large vessels nearby. Local anaesthesia is therefore suitable. The operation, however, should not be underestimated or undertaken for insignificant nodes. The surgeon must be aware of the surface markings of the accessory nerve when removing level V nodes, as the nerve crosses the posterior triangle at the level of the deep fascia (Figure 10.7). The nodes lie in close proximity to the nerve, which is thus extremely vulnerable to injury either from surgical division or diathermy damage. Accessory nerve injury results in significant shoulder dysfunction.

Deep cervical nodes are deep to sternocleidomastoid and general anaesthesia and a protected airway are recommended. A transverse incision through skin and platysma, followed by posterior retraction of the sternocleidomastoid muscle after incision of the deep cervical fascia along its anterior border, will bring the surgeon into the correct plane. Care must be taken not to damage the internal jugular vein; its anterior tributaries, such as facial and thyroid veins, may have to be ligated and divided.

Supraclavicular nodes are often deceptive and found at operation to be deeper than initially suspected. They may merely be the only accessible part of a huge mass of matted mediastinal nodes, which are compressing the trachea and distorting the anatomy of the great vessels at the root of the neck. The surgeon should dissect with caution under optimum surgical and anaesthetic conditions. Tracheal compression in the superior mediastinum can make a general anaesthetic hazardous, but this is also a hazardous area for a surgeon to operate under local anaesthesia.

Neck dissection

The classical *radical neck dissection* described by Crile in 1906 included the *en bloc* excision of all cervical lymph nodes along with the sternocleidomastoid muscle, the internal

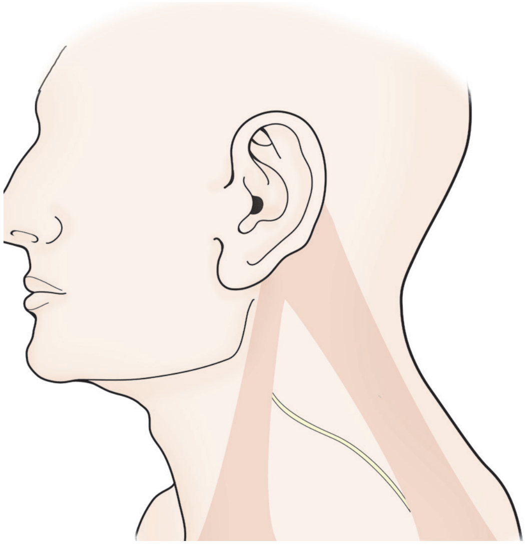

Figure 10.7 *The accessory nerve crosses the posterior triangle at the level of the deep fascia. The surface markings are from the junction of the upper and middle third of sternocleidomastoid to the junction of the middle and lower third of trapezius. Level Va occipital lymph nodes lie in close proximity to the nerve.*

jugular vein and the accessory nerve.[4] Most surgeons now prefer to preserve some of these non-lymphatic structures, even in the neck dissections for head and neck malignancies. Preservation of function in the accessory nerve is particularly desirable. Such dissections are described as *modified radical neck dissections*, and these are classified as:

- Type I, with preservation of the accessory nerve.
- Type II, with preservation of the accessory nerve and the internal jugular vein.
- Type III, with preservation of the accessory nerve, internal jugular vein and sternocleidomastoid.

A *selective neck node dissection* preserves one or more lymph node groups in addition to the three non-lymphatic structures. For example, a level VI selective dissection is employed commonly in thyroid cancer.

The incisions for any form of radical neck dissection must be planned to afford good access and leave inconspicuous scars. In addition, skin viability must be preserved, as a carotid artery exposed by skin breakdown has a risk of rupture. The blood supply to the skin of the lateral neck comes from all directions, with a resultant relatively poorly vascularised central area directly over the common carotid artery (Figure 10.8a). Vertical incisions and three-point junctions in this central area should therefore be avoided, especially when radiotherapy has already been used and salvage surgery is being undertaken. Suitable incisions for radical neck dissections are shown in Figure 10.8b.

The skin flaps are elevated to include the platysma. In the submandibular area, in order to preserve the marginal mandibular branch of the facial nerve, the nerve is formally identified. If this is difficult, the flaps should be elevated by dissection in a deeper plane. This plane is on the body of the submandibular gland and the fascia over the gland is included in the flap.

Inferiorly, the sternal and clavicular heads of sternocleidomastoid are divided to expose the carotid sheath. The internal jugular vein is isolated by dissection around it and the vagus nerve, lying in a deep plane between the vein and the common carotid artery, is identified and preserved. The vein is then divided between ligatures. On the left, the thoracic duct is commonly divided at this point and will require oversewing to prevent leakage. The dissection is continued laterally, above the prevertebral fascia, to the anterior border of trapezius, elevating the fat pad overlying the scalene muscles and dividing the inferior belly of the omohyoid muscle, which is included in the specimen. The external jugular vein and supraclavicular cutaneous nerves must also be divided. The transverse cervical vessels lie between the fat pad and the prevertebral fascia and should, if possible, be preserved. Underneath the prevertebral fascia, the phrenic nerve runs medially and downwards on scalenus anterior. It is identified and preserved. The trunks of the brachial plexus are also beneath this fascia. Bipolar diathermy is therefore preferable to monopolar diathermy for this dissection so close to the nerves.

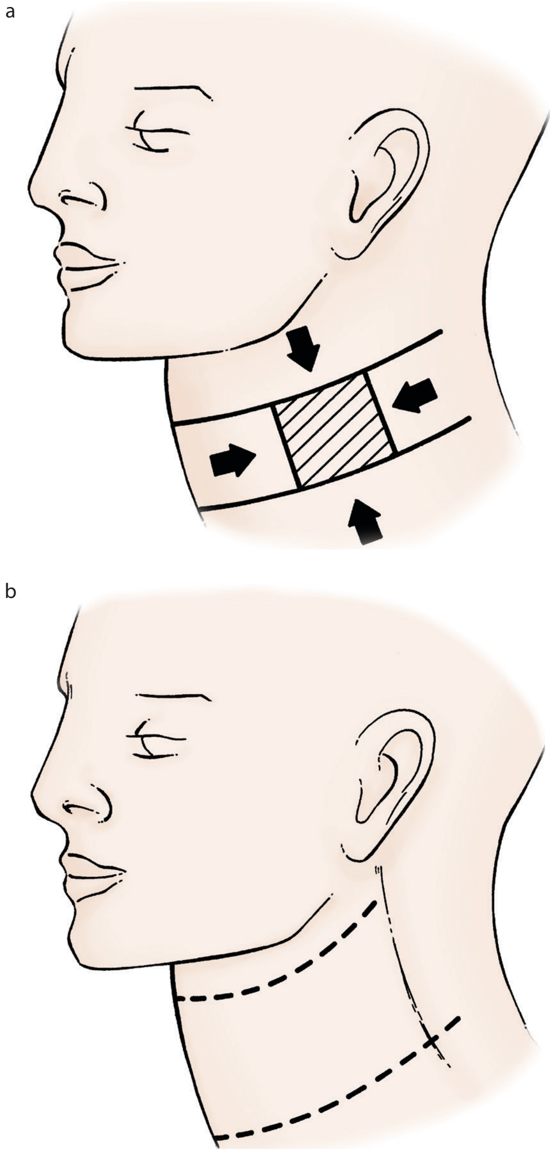

Figure 10.8 *(a) The shaded area has the poorest blood supply in the neck. It also overlies a relatively superficial segment of the carotid arteries. (b) Incisions that afford excellent exposure but avoid vertical incisions or three-point junctions in this area of skin.*

Posteriorly, the limit of dissection is trapezius, and the dissection is continued up along its anterior border (Figure 10.9a). The transverse cervical artery gives a vertical branch, which runs up the anterior border of trapezius and requires formal ligation and division. The accessory nerve is divided in the classical radical dissection as it enters the muscle, but is preserved in all modified neck dissections. The upper third of the trapezius approaches the posterior border of the sternocleidomastoid muscle, the fibres of which are divided close to their mastoid insertion.

Anteriorly, the superior belly of the omohyoid muscle forms the boundary of the dissection and is followed to its insertion into the hyoid bone and divided (Figure 10.9b).

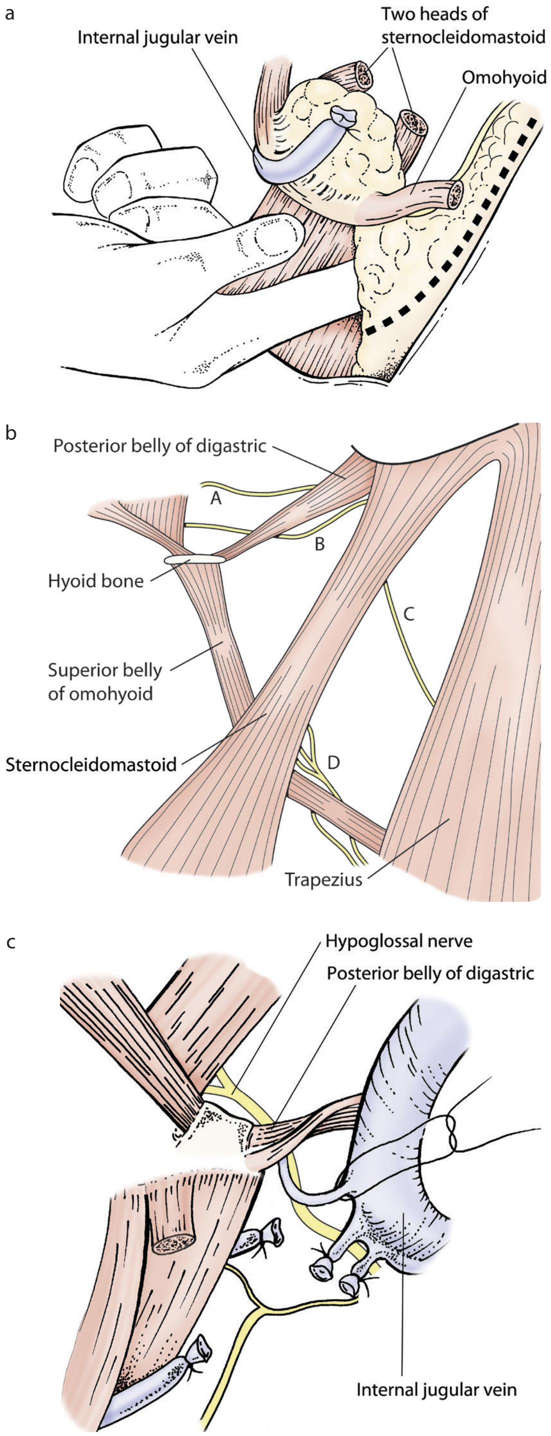
a
Internal jugular vein
Two heads of sternocleidomastoid
Omohyoid
b
Posterior belly of digastric
A
B
Hyoid bone
C
Superior belly of omohyoid
Sternocleidomastoid
D
Trapezius
c
Hypoglossal nerve
Posterior belly of digastric
Internal jugular vein

Figure 10.9 *Radical neck dissection on the left. (a) The fat pad with the divided inferior belly of omohyoid, the two heads of sternocleidomastoid and the internal jugular vein are turned up. The surgeon's finger is on scalenus anterior and the incision will next be extended up the anterior border of trapezius along the dotted line. (b) The muscles that form the landmarks for a radical neck dissection are shown with some of the nerves. A = marginal mandibular branch of the facial; B = hypoglossal; C = accessory; D = brachial plexus. The superficial nerves have been omitted and the phrenic nerve is hidden by sternocleidomastoid. (c) At the upper limit of the dissection the hypoglossal nerve is vulnerable. The small veins that cross the nerve require individual ligation and division.*

The submental fat pad is dissected off until the anterior bellies of both digastric muscles are identified.

The *deep dissection* is commenced by reflecting forwards the posterior margin of the dissection and releasing the fat pad, with the nodes, off the prevertebral fascia and the underlying muscles, the levator scapulae and the scalenes. The specimen is tethered by the four cutaneous branches of the cervical plexus, namely the transverse cervical, the greater auricular, the supraclavicular and the lesser occipital nerves. These nerves are identified and divided well away from the phrenic nerve. The internal jugular vein is dissected out of the carotid sheath up to the jugular foramen. The transverse process of the atlas is palpated and, just above this, the posterior belly of digastric will be found. This is retracted upwards and the upper end of the jugular vein exposed, where it is again divided between ligatures, with care being taken to preserve the vagus nerve. The hypoglossal nerve can be seen crossing lateral to the external carotid artery, and is in turn crossed by three small veins draining from the tissue to be excised. These vessels must be ligated and divided or they will tear, and attempts to stop the bleeding will endanger the hypoglossal nerve (Figure 10.9c). The remaining sternocleidomastoid fibres are divided at the level of a line extending from the tip of the mastoid process to the angle of the jaw. A higher division places the facial nerve at risk, as it lies deep to the anterior border of the muscle.

Superiorly, the submental fat pad and the anterior edge of the submandibular gland are dissected off the lateral surface of the mylohyoid muscle. The submental artery will require ligation and division. The posterior edge of mylohyoid is then retracted forwards and the gland retracted inferiorly to expose the lingual nerve, which is freed and preserved. The submandibular duct is ligated. The facial vessels are ligated at the upper border of the gland and the facial artery again at the inferior border.

COMPLICATIONS

Immediate complications include haemorrhage and pneumothorax and raised intracranial pressure from compromised venous drainage. Necrosis of skin flaps, with exposure of the carotid artery, is a serious intermediate-term complication that requires further surgery at the earliest opportunity to cover the vulnerable vessel. A chylous fistula from injury to the thoracic duct is initially treated conservatively, but occasionally may require surgical intervention (see Chapter 18). Shoulder dysfunction is inevitable if the accessory nerve has been sacrificed.

Tuberculous cervical lymphadenitis

This condition is still encountered where bovine tuberculosis is common. Untreated nodes caseate and discharge. Cold abscesses with adherent overlying skin proceed to chronic discharging sinuses and severe scarring. Surgery is seldom indicated if antituberculous treatment is effective, although limited surgery in conjunction with effective chemotherapy is sometimes appropriate. The emergence of multiresistant strains, however, means that once again the surgeon may have to operate for this condition when no other treatment is effective. Tuberculous cervical lymphadenitis is almost invariably unilateral, and 90 per cent involve only one group of glands, the most common being the deep nodes beneath the sternocleidomastoid muscle, followed by the submandibular group.

When surgery is undertaken for resistant disease, it must include excision of all diseased nodes if it is to offer a reasonable chance of eradication of the infection. This can, however, be a challenging operation when the deep cervical nodes are matted and adherent to the internal jugular vein, the wall of which may form the medial wall of the tuberculous abscess. A dissection similar to the radical neck dissection described above may be necessary to secure the internal jugular vein above and below the segment of involved vein, which has to be removed *en bloc* with the specimen. The accessory nerve and the sternocleidomastoid muscle can usually be preserved.

Cystic hygroma

These are congenital cystic abnormalities of the cervical lymph vessels and may be so large as to obstruct labour or compress and obstruct the newborn airway. The urgency of surgery will depend on size, but specialist referral is appropriate. Large lesions may extend down into the superior mediastinum and the deeper aspects may have to be dissected off the internal jugular vein. Superiorly, the multiloculated cyst may extend into the parapharyngeal space and the floor of the mouth. Dissection of the superior extensions places the facial nerve at risk and a formal superficial parotidectomy may be necessary to safeguard its branches. Staged surgery or repeat resections are often necessary.

THE THYROID AND PARATHYROID GLANDS

Surgical anatomy

THYROID GLAND

The thyroid lies in the lower part of the front of the neck as a bilobed gland joined by an isthmus that overlies the second to fourth rings of the trachea. The lobes lie lateral to the larynx and trachea and are in close apposition to them. A gland of normal size extends from the middle of the thyroid cartilage to just above the clavicle. The gland is enclosed in a sheath of pre-tracheal fascia, so that it moves on swallowing. Superficially, it is covered by the sternothyroid and sternohyoid strap muscles.

Blood supply

The thyroid gland's blood supply is from the superior and inferior thyroid arteries. The *superior thyroid artery* is the first anterior branch of the external carotid artery. It passes down to the upper pole of the thyroid lobe. The *inferior thyroid artery* arises from the thyrocervical trunk, a branch of the subclavian artery. It runs upwards and medially behind the carotid sheath to enter the middle of the back of the lobe. The *superior thyroid vein* leaves the gland with the superior thyroid artery and drains into the internal jugular or facial vein. The *middle thyroid veins* emerge from the lateral aspect of the lobe and cross in front of the common carotid artery to join the jugular vein. The *inferior thyroid veins* emerge from the isthmus and lower medial part of the lobe and descend in front of the trachea to end in the left brachiocephalic vein.

Regional nerves

These nerves are in danger in any operation on the thyroid or parathyroid glands. The *external laryngeal nerve*, which is a terminal branch of the superior laryngeal branch of the vagus, runs downwards on the inferior pharyngeal constrictor, deep and medial to the upper pole of the thyroid gland, to end by supplying the cricothyroid muscle. Near its termination it is in close proximity to the superior thyroid artery and is vulnerable when this vessel is ligated. The *recurrent laryngeal nerve* supplies all the intrinsic muscles of the larynx. It arises from the vagus on the right side as it crosses the subclavian artery and on the left as it crosses the aorta. It hooks around the artery and ascends in the groove between the trachea and the oesophagus. It enters the larynx below the lower border of the inferior constrictor and is here closely related to the termination of the inferior thyroid artery, where it is vulnerable when this vessel is ligated. Anatomical anomalies, more common on the right, include a nerve following a more lateral course, which then runs obliquely or even horizontally towards the larynx alongside, or anterior to, the inferior thyroid artery and is therefore more vulnerable to injury.

PARATHYROID GLANDS

The parathyroid glands consist of bilateral superior and inferior glands that lie behind the thyroid. Each is ellipsoid and pea-sized and of a reddish-brown colour. Considerable variation in position is common, but classically the glands lie within 1–2 cm of the intersection of the recurrent laryngeal nerve and the inferior thyroid artery. The *superior glands* lie above and behind the nerve. The *inferior glands* lie below and in front of the nerve.

Thyroid and parathyroid surgery

A secure airway and good access for the surgeon are essential. These are usually achieved by a general anaesthetic with endotracheal intubation and the head towelling technique shown in Figure 10.1. The patient is positioned supine with a sandbag under the shoulders, the neck is extended and the occiput supported on a head ring.

EXCISION OF A THYROGLOSSAL CYST

The thyroid gland develops from the thyroglossal duct, which grows down from the foramen caecum at the junction of the middle and posterior third of the tongue. Incomplete regression of the duct results in a thyroglossal cyst or fistula. The cyst is in the midline, either above or below the hyoid, and moves with swallowing and tongue protrusion, unlike a thyroid swelling, which moves only with swallowing. A fistula is usually secondary to spontaneous discharge or drainage of an infected thyroglossal cyst. The treatment of both a cyst and a fistula is excision. In order to prevent recurrence, the remnant of the thyroglossal duct must be traced upwards and excised.

A horizontal incision is made over the cyst or an ellipse is cut to include a fistula. The platysma is divided in line with the skin incision, the deep cervical fascia is divided vertically in the midline and the strap muscles are separated. The cyst is mobilised and the upward extension of the track is followed until it disappears deep to the body of the hyoid bone, to which it is densely adherent (Figure 10.10). The hyoid must then be separated from the underlying thyrohyoid membrane. There is a space between these structures, and the surgeon's fears of encountering the endotracheal tube in the operating field are normally groundless. The central 1 cm of the hyoid bone is cleared of muscle attachments and is then resected with bone nibblers so that it can be removed with the specimen. The dissection can then proceed into the tongue towards the foramen caecum. The track often disappears at this level and entry into the oral cavity is unnecessary. The wound is closed with vacuum drainage.

HEMITHYROIDECTOMY

Hemithyroidectomy (thyroid lobectomy) is undertaken usually for diagnostic purposes, when preoperative investigations of an apparently solitary thyroid nodule have neither excluded nor confirmed malignancy. Imaging with ultrasound scanning identifies whether the nodule is solitary or, as is quite common, is a dominant nodule in a multinodular goitre. It also differentiates solid from cystic nodules. Technetium uptake scanning will differentiate functioning ('hot') nodules from non-functioning ('cold') ones. Fine-needle aspiration cytology can diagnose colloid nodules, lymphoma and papillary, medullary and anaplastic cancer. It cannot, however, differentiate benign from malignant follicular tumours.

The commonest indications for hemithyroidectomy include a solitary cold nodule with follicular cytology and a dominant cold nodule in a multinodular goitre with follicular cytology and where the multinodular changes are confined to one lobe. A hemithyroidectomy is required for definitive histological diagnosis. A perioperative frozen section is advocated by some, but most pathologists find that differentiating benign from malignant follicular tumours is a particular problem, although the technique is useful in confirming a papillary carcinoma (which may be suspected but has not been proven on the basis of the preoperative cytology). Alternatively, a definitive pathology report is awaited and completion thyroidectomy, if indicated, undertaken as a separate later procedure.

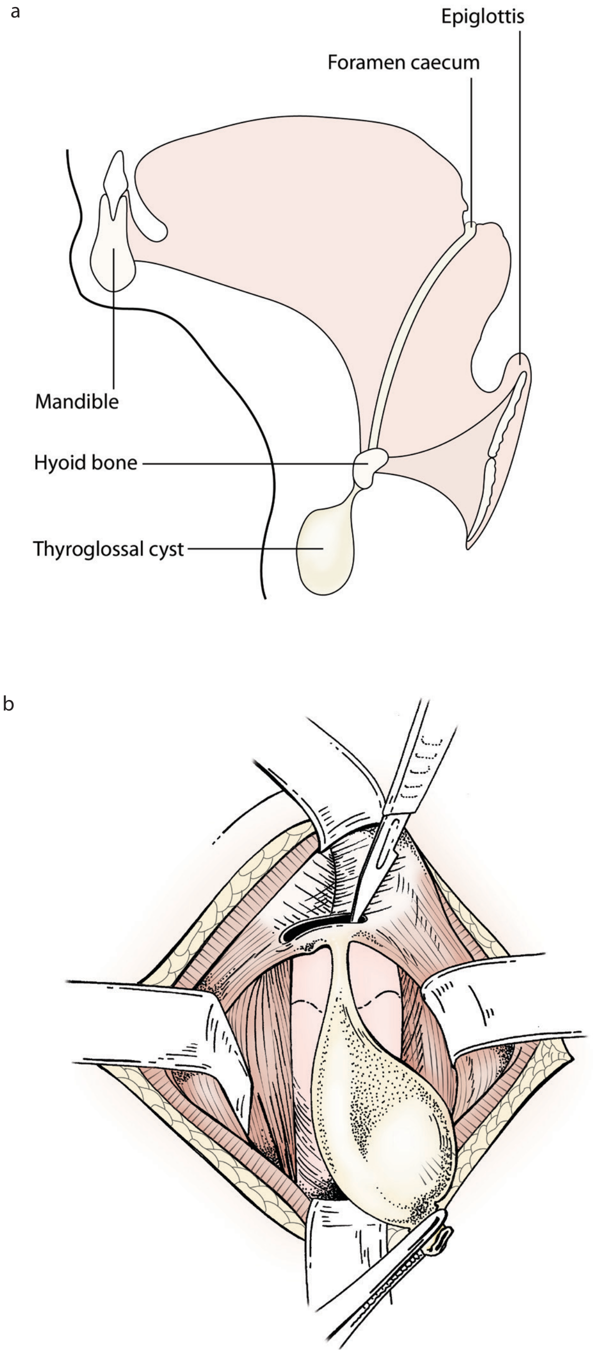

Figure 10.10 *(a) The track from a thyroglossal cyst or sinus is intimately related to the hyoid bone and ends at the foraman caecum. (b) If the central portion of the hyoid is not excised with the adherent track on its deep surface, recurrence is likely.*

In young women, who form a lower risk group if they have papillary or follicular thyroid cancers under 1 cm in diameter, a hemithyroidectomy may be adequate definitive surgical treatment. Numerous guidelines have been produced in recent years and although there is general agreement, debate over management still continues.[5,6]

While medullary thyroid cancer is rare, it is generally managed in a more radical manner and preoperative diagnosis, when possible, permits selective surgery. In particular, more extensive nodal surgery is undertaken and this is easier if it is not complicated by previous thyroid surgery. When a preoperative diagnosis of differentiated thyroid cancer has been made, the possibility that this might be medullary cancer should be considered and this can be confirmed or refuted with either cytological immunostains for calcitonin or a serum calcitonin measurement.

The operation

A slightly curved transverse skin crease incision is made 2–3 cm above the sternum (it should not be positioned lower than this or the central portion of the scar will hypertrophy). Platysma is incised in line with the skin and the skin and platysma flaps are elevated down to the sternum and up to the thyroid cartilage. Traditionally, 40–60 ml of 1 in 400,000 adrenaline was infiltrated into the superficial tissue of the flaps prior to the incision to reduce bleeding, but this is of less value when diathermy dissection is employed. A self-retaining Joll's retractor can be used to retract the flaps. The deep cervical fascia is incised vertically in the midline and the strap muscles retracted laterally (Figure 10.11a). Horizontal division of the strap muscles for access is seldom necessary, even in large goitres, as the muscles in this situation have already been stretched by the enlarged gland. If division is necessary, the muscles should be divided high up, as their innervation is from below. They are repaired at the end of the procedure.

The assistant retracts the strap muscles laterally and away from the surface of the gland. Areolar tissue around the gland is divided and the middle and inferior thyroid veins are displayed. These require ligation and division. Skilled assistance is essential for this operation as these veins are unsupported by surrounding tissue and are very delicate. The artery forceps must be released with minimal movement of the tip as the surgeon tightens the ligature. Alternatively, an aneurysm needle can be used to pass the ligature around the vein, which is then ligated in continuity before division. The deepest of the inferior thyroid veins may be in close proximity to the recurrent laryngeal nerve, and the final ligations in this area may have to wait until the nerve has been identified. Attention is next turned to the superior pole. With gentle traction on the now partially mobilised lobe, it should be possible to pass a right-angled forceps behind the superior pole vessels and pass a mounted tie around them (Figure 10.11b). An aneurysm needle is also very useful for this step. The external laryngeal nerve is endangered during this manoeuvre, and it is important to try and find the window medial to the superior pole vessels and stay a few millimetres lateral to the surface of the larynx. The ligature is then tied as low as possible. A second ligature is tied above it, and an artery forceps is placed immediately above this second ligature. The vessels

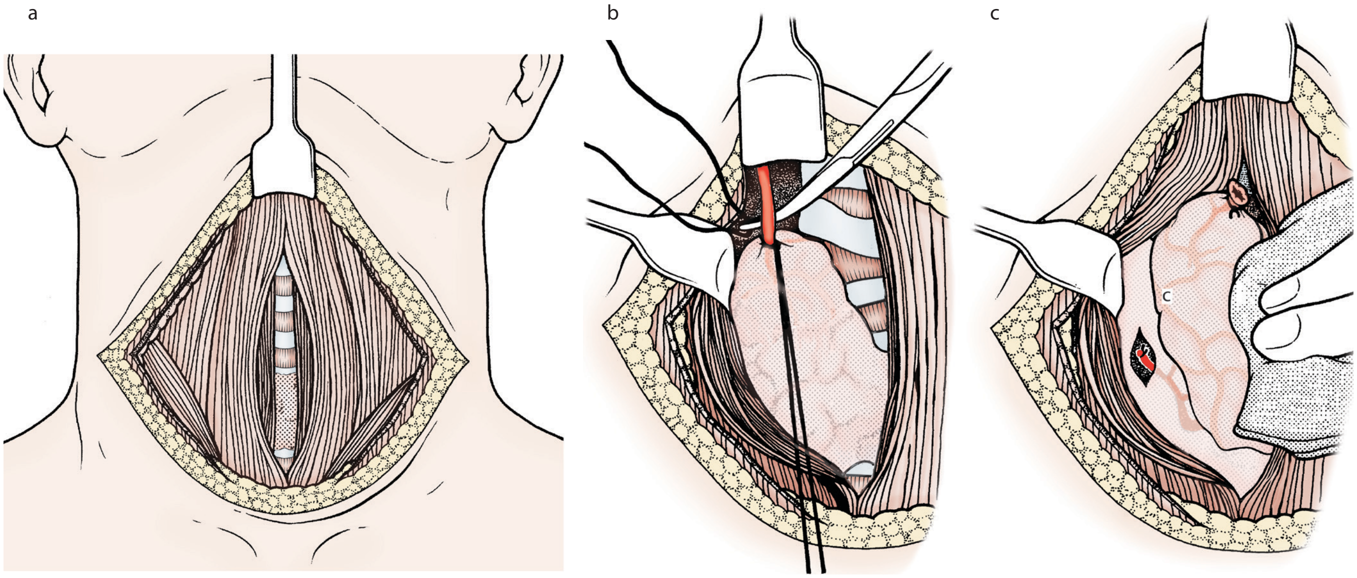

Figure 10.11 *A right thyroid lobectomy. (a) A horizontal skin and platysma incision is followed by elevation of the flaps. Vertical midline division of the cervical fascia and separation of the strap muscles exposes the gland. (b) The right strap muscles are retracted. Multiple small veins have been divided, and retraction has exposed the upper thyroid pole. The first ligature has been tied around the superior thyroid vessels close to the gland. (c) The retractor is now in a deeper plane and is retracting laterally the carotid sheath in addition to the strap muscles. The thyroid is retracted medially. An incision through the posterior fascia allows identification of the recurrent nerve, running in a vertical or oblique orientation. The inferior thyroid artery crosses the nerve. The artery runs transversely and can be seen to pulsate. The branches of the artery should be divided on the surface of the thyroid distal to the parathyroids.*

are then divided between the ligatures and a further ligature tied on the superior thyroid pedicle before the forceps is released. Too high a tie of these vessels also endangers the external laryngeal nerve. Many surgeons are now using the Harmonic® scalpel for division of all the thyroid vasculature.

The lobe is then rotated medially out of its bed. The assistant is now retracting in a deeper plane and the retractor is drawing the carotid sheath laterally. The inferior thyroid artery and the recurrent laryngeal nerve must now be displayed; both lie beneath a fascial layer, which must be incised (Figure 10.11c). The inferior thyroid artery was traditionally then ligated in continuity, as lateral as possible to minimise any danger to the nerve. It is now recommended instead that close dissection is continued after the nerve has been identified and the branches of the inferior thyroid artery are secured on the surface of the gland, in order to preserve parathyroid vasculature.

The final dissection of the deep portion of the gland off the recurrent nerve and the parathyroids is the most difficult, and must be performed with great precision. The medial surface of the lobe then separates easily from the trachea and is finally only attached by the isthmus, which is divided close to the contralateral lobe. A haemostatic continuous absorbable suture in the isthmus will control haemorrhage or, alternatively, it can be divided with the Harmonic® scalpel.

A deep vacuum drain is placed beneath the strap muscles before they are approximated. The platysma is sutured and finally the skin is closed using sutures or staples.

TOTAL THYROIDECTOMY

This is the standard operation for thyroid cancer. It is also increasingly employed for multinodular goitre and for the surgical management of thyrotoxicosis that has relapsed on medical treatment. It is also undertaken prophylactically in patients who are genetically at high risk of familial medullary thyroid cancer. The indication for excision of the whole thyroid in papillary and medullary cancer is the commonly multifocal pattern of the disease. In follicular cancer the rationale is complete eradication of thyroid tissue so that any metastases can be identified and treated by uptake of radioactive iodine. If a definitive preoperative diagnosis is possible, as discussed in the section on hemithyroidectomy, a total thyroidectomy can be planned from the outset.

Operative procedure

Surgery is essentially a bilateral hemithyroidectomy, but the risks involved are higher. Unilateral recurrent nerve damage leaves a patient with a deeper voice of reduced strength. Bilateral damage results in the paralysed cords migrating medially to obstruct the airway, and a tracheostomy may be necessary. In addition, bilateral loss of parathyroid function, whether from excision or from ischaemic damage, may produce symptomatic hypocalcaemia. Thyroid replacement therapy will, of course, always be necessary.

LYMPH NODE DISSECTIONS WITH THYROIDECTOMY

Surgical opinion is divided on the prognostic value of the diagnosis of nodal metastases in differentiated thyroid cancer. There is agreement, however, that if nodal dissection is necessary, a type III modified or functional dissection is undertaken. Opinion is also divided over the therapeutic value of prophylactic dissection of the clinically negative neck and whether it should be preceded by frozen section histology of the nodes. Preoperative imaging of cervical nodes, usually by ultrasound or CT scanning, can raise the suspicion of nodal metastases and cytological confirmation permits a more planned approach to surgery.

In *papillary thyroid cancer*, one view is that in addition to a total thyroidectomy, the pretracheal and tracheo-oesophageal lymph nodes (level VI) are cleared, as this cervicocentral group is the most commonly involved. Frozen section histology can then be obtained of a node in the middle portion of the ipsilateral deep cervical chain, as in the cervicolateral region it is these level III nodes that most frequently will contain metastases. If this node is positive, a type III modified radical neck dissection is performed. Many surgeons, however, would elect for a total thyroidectomy without any lymph node dissection in the clinically negative neck, especially when preoperative imaging has also been negative.

In *follicular thyroid cancer*, lymph node metastases are less common than in papillary cancer, but distant metastases are more common. Although this changes the balance of risk, the issues that dictate the surgical strategy in the clinically negative neck are similar.

In *anaplastic thyroid cancer* little is gained by radical surgery. Radiotherapy and chemotherapy may procure a short remission, and surgery is restricted to excision of the isthmus to prevent airway obstruction.

In *medullary thyroid cancer* the central and paratracheal lymph nodes (level VI) should be excised, and this dissection can be continued caudally to include upper mediastinal (level VII) nodes and the thymus gland. The deep lateral cervical nodes may also contain metastases. The advisability of a unilateral or bilateral modified neck dissection can again be determined on frozen section histology of a deep cervical node.

SUBTOTAL THYROIDECTOMY

This was the standard operation both for a large goitre and for a toxic thyroid. In subtotal thyroidectomy, the remnant is left mainly to safeguard the parathyroid glands and their blood supply and to reduce the risk of injury to the recurrent laryngeal nerve. More recently, total or near total thyroidectomy and thyroid replacement therapy have been advocated for both conditions, primarily to reduce the risk of recurrence of the goitre or of thyrotoxicosis.

In a large *multinodular goitre* the aim may be purely cosmetic, but more commonly there are pressure effects on the trachea and, ultimately, on the oesophagus. *Hyperthyroidism* is primarily a medical condition. Surgery is indicated for patients who relapse after medical treatment and for those in whom the gland is nodular and enlarged in addition to being hyperactive. Thyrotoxicosis must be controlled by medical means prior to surgery. Antithyroid drugs are now commonly combined with beta-receptor blockade to prevent the cardiovascular manifestations of an increase in circulating thyroxine. Following total or near total thyroidectomy, patients will become hypothyroid without thyroxine replacement therapy. After a classical subtotal thyroidectomy, hypothyroidism is related more to the nature of the disease and the immunological changes triggered by the surgery, than to whether the correct volume of thyroid remnant was retained. Traditionally, the surgical belief was that approximately one-eighth of the original gland should be retained.

Operative procedure

Subtotal thyroidectomy proceeds in the same fashion as for a total thyroidectomy until after the inferior thyroid artery (or its branches) is ligated. The lobes are then transected, leaving a cuff of posterior thyroid tissue, which lies on either side of the trachea from which the overlying isthmus has been removed (Figure 10.12). A continuous haemostatic suture may be inserted in each transected remnant, but with great care, as the residual thyroid tissue overlies the recurrent laryngeal nerve and the parathyroid glands.

RETROSTERNAL GOITRES

The whole thyroid gland may be lying retrosternally or, more commonly, there is a retrosternal portion of a large goitre. The goitre is frequently symptomatic, and surgery is indicated for tracheal compression. The retrosternal goitre lies in the superior mediastinum above and anterior to the great vessels. It can usually be delivered up into the neck without difficulty. In situations where it cannot be delivered easily, the proximity to these vessels must be remembered and force avoided. Extremely rarely, a median sternotomy is necessary for safe mobilisation of a retrosternal goitre (see Chapter 8).

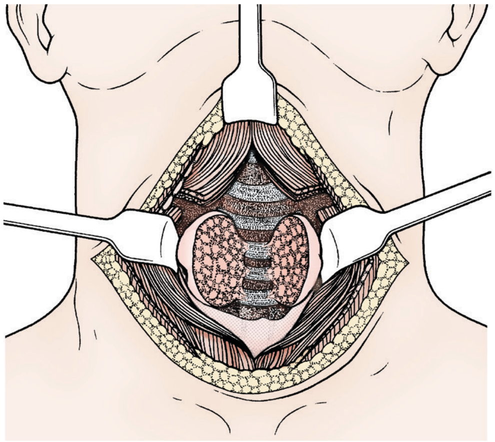

Figure 10.12 *Subtotal thyroidectomy. A small remnant of each lobe has been left bilaterally. The illustration shows a case in which partial division of the strap muscles proved necessary.*

PARATHYROIDECTOMY

Parathyroidectomy is undertaken for hyperparathyroidism. *Primary hyperparathyroidism* is usually the result of a secreting adenoma in one gland. The remaining glands are small and hormonally suppressed. However, a spectrum of adenoma and hyperplasia can occur, particularly in some forms of the multiple endocrine neoplasia (MEN) syndrome. In patients with renal pathology the initial hormonal abnormality is a compensatory *secondary hyperparathyroidism*, with hyperplasia affecting all four glands. Finally, the overactive glands may become autonomous and a *tertiary hyperparathyroidism* develops, which commonly involves more than one gland in hyperplastic or adenomatous change. When there is a solitary adenoma, only that gland should be excised, particularly when preoperative ultrasound and sestamibi (MIBI) scans correlate. When a hyperplastic process involves all the glands, it has been commonly advocated that three glands and half of the fourth gland should be excised. More recently, removal of all four glands and maintenance replacement therapy with 1,25-dihydroxycholecalciferol has gained popularity, primarily to reduce the risk of recurrent hypercalcaemia. The operative strategy of surgeons operating on this condition will thus vary, depending on whether their referral practice is mainly of patients from a regional renal centre.

For the management of sporadic primary hyperparathyroidism it is important to identify the side and position of what will be a solitary adenoma in 80 per cent of cases. This avoids unnecessary bilateral exploration in the majority of patients. An ultrasound, CT or MRI scan may demonstrate an enlarged gland. MIBI scans initially proved invaluable before re-explorations, but they are now used routinely before most parathyroid surgery. A combination of a positive MIBI scan and an anatomical scan showing concordance results in a 95 per cent chance that the solitary adenoma will be found in the co-localised position. Prior to a re-exploration these investigations can be repeated and additionally, selective venous sampling can be helpful. Patients with hyperparathyroidism secondary to renal disease will require a bilateral neck exploration, as will those with a familial predisposition and those whose preoperative scans suggest multigland disease. However, the 80 per cent of patients with suspected primary hyperparathyroidism only require a unilateral exploration on the side of the adenoma. Removal of one enlarged gland, with perioperative frozen section confirmation that it is parathyroid, and identification of one normal gland are sufficient.

Operative procedure

Methylene blue is taken up selectively by the parathyroids, and the blue staining of the tissue is helpful in differentiating parathyroid tissue from lymph nodes or nodules of fat. It is administered in solution, as an infusion of 5 mg/kg over a 1-hour period. The colour differential diminishes after a further hour, and timing of the infusion can be difficult.

Frozen section histology should be used for confirmation. The parathyroid adenoma may be immediately apparent after mobilisation of the thyroid, but sometimes parathyroid glands cannot be identified and may be lying in ectopic positions.[7,8] A *superior* gland that is not in its normal position is often lying more *dorsally* and adjacent to the oesophagus, and may have migrated caudally as far as the posterior mediastinum. An *inferior* gland lies more *ventrally*, but it may have migrated caudally to lie in the anterior mediastinum or cranially to lie close to the submandibular gland. Parathyroid glands may also lie within the thyroid tissue. It must be remembered that 3 per cent of individuals have only three glands and 13 per cent have supernumerary glands.

Over the last decade there has been an increasing interest in minimally-invasive video-assisted thyroid and parathyroid surgery.[9] In some centres, parathyroid surgery is increasingly undertaken by this method.[10]

REVISION SURGERY ON THE THYROID AND PARATHYROID GLANDS

Reoperation, whether for excision of the remnant of a thyroid lobe, excision of a recurrent goitre or repeat exploration for recurrent hyperparathyroidism, carries a greatly increased risk of damage to the recurrent laryngeal nerve. The anatomy may be both obscured and distorted by scar tissue, and the planes for safe dissection are obliterated. Avoidance of these problems is one of the reasons why total thyroidectomy is gaining in popularity. Surgery for a recurrent goitre may be requested on purely cosmetic grounds and should not be undertaken lightly. When reoperation is necessary, the surgeon must take extra care during dissection and the patient must be warned preoperatively of the increased risk of nerve damage. Referral to a surgeon with special expertise should always be considered in this situation.

POSTOPERATIVE COMPLICATIONS OF THYROID AND PARATHYROID SURGERY

Airway complications

Postoperative stridor can occur for several reasons:

- *Bilateral recurrent nerve damage*: an immediate problem with maintenance of the airway on extubation will occur if there has been bilateral nerve damage. Laryngoscopy confirms paralysed adducted cords obstructing the airway. Reintubation will have to be followed by a tracheostomy, which will usually be permanent unless the damage is no more than a temporary neuropraxia.
- *Tracheomalacia* is a complication of very large goitres and is therefore seldom encountered in surgical practice in the developed world. Airway obstruction from postoperative tracheal collapse may necessitate an emergency tracheostomy. When tracheomalacia is recognised intraoperatively, an elective temporary tracheostomy should therefore be considered.
- *Haemorrhage* deep to the strap muscles compresses, and finally occludes, the airway. Treatment consists of opening the wound to drain the haematoma and relieve the pressure. There is frequently some warning of this impending disaster, and the patient can be returned to the operating theatre for urgent intervention. When warning signs have been ignored, an acute emergency may present for which restoration of the airway in an unconscious anoxic patient must be achieved immediately. Sutures in the skin, platysma and strap muscles are cut at the bedside, the clot is evacuated and the patient then returned to theatre for resuturing of the wound. Clip removers should always be readily available at the patient's bedside for this emergency if clips have been used for skin closure.

Biochemical complications

Early and late disturbances in thyroid and parathyroid endocrine balance are common:

- A *thyroid crisis* can occur postoperatively in a patient whose thyrotoxicosis was inadequately controlled preoperatively. Management is medical, with sedation and beta blockade. Preoperative control of thyrotoxicosis is therefore very important.
- *Hypothyroidism* is inevitable after a total thyroidectomy and is a common late complication of a subtotal thyroidectomy. It also occurs in over 10 per cent of patients following a hemithyroidectomy. Hypothyroidism does not, however, pose problems in the immediate postoperative period, and thyroxine replacement therapy should be delayed initially if thyroidectomy is undertaken for differentiated thyroid cancer, as postoperative radioactive iodine scanning is facilitated by thyroid-stimulating hormone stimulation.
- *Hypocalcaemia* is the manifestation of insufficient parathyroid hormone secretion. Parathyroid glands may have been excised or rendered ischaemic by surgery. Presentation with tetany should be avoidable, as postoperative assessment of serum calcium is mandatory. This allows calcium and, if necessary, 1,25-dihydroxycholecalciferol support to be given should hypocalcaemia develop. Spontaneous recovery of parathyroid function is common.

THE SALIVARY GLANDS

Surgery of the parotid and submandibular glands requires a detailed understanding of the anatomy.

The parotid gland

Any surgery on the parotid gland risks injury to the facial nerve. Surgeons who operate infrequently in this area are more likely to injure the nerve, and for this reason a parotidectomy is now seldom undertaken by a generalist, who instead will refer a patient to a head and neck specialist.

SURGICAL ANATOMY

The parotid gland lies in the space behind the mandible, below the external ear, in front of the mastoid process, and extends forwards on the lateral surface of the masseter. The gland overlies the posterior belly of digastric below and deeply it is adherent to the styloid process and its muscles. It is enclosed in a sheath, which is derived from the deep cervical fascia and sends processes into the gland to divide it into lobules. The *upper pole* of the gland lies just below the zygomatic arch and is wedged between the meatus and the mandibular joint. The superficial temporal vessels, the temporal branches of the facial nerve and the auriculotemporal nerve are found entering or leaving the gland near the upper pole. The marginal mandibular and cervical branches of the facial nerve and the two divisions of the retromandibular vein emerge from the *lower pole.* From the *anterior border* emerge the zygomatic and buccal branches of the facial nerve and, on a deeper plane, the parotid duct.

The *external carotid artery* ascends through the deep part of the gland. It terminates behind the neck of the mandible by dividing into maxillary and superficial temporal arteries. The *facial nerve*, after emerging from the stylomastoid foramen, almost immediately enters the posteromedial surface of the gland and after about 2 cm splits into two main subdivisions, from which the terminal branches arise. The *retromandibular vein* forms within the substance of the gland by the union of the superficial temporal and maxillary veins and emerges from the lower pole usually as two trunks. The anatomy is remarkably consistent, with the nerve and its branches lying just superficial to the veins (Figure 10.13). The *faciovenous plane,* in which the veins and the branches of the facial nerve lie, arbitrarily divides the gland into a superficial and a deep part. It was the appreciation of this anatomy that allowed surgery on the parotid with preservation of the facial nerve.[11]

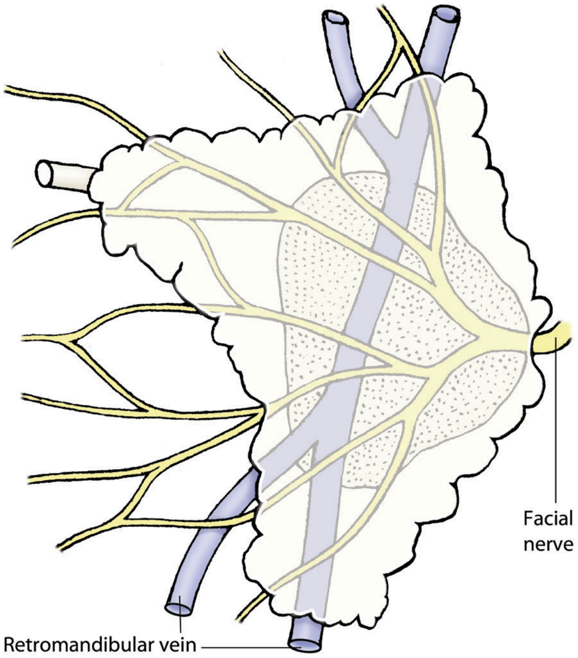

Figure 10.13 *The faciovenous plane as described by Patey and Ranger. The retromandibular vein traverses the gland in a vertical direction, while the facial nerve trunk enters posteriorly and its branches fan out to leave the gland superiorly, anteriorly and inferiorly.*

REMOVAL OF A PAROTID DUCT CALCULUS

A calculus impacted in the duct and obstructing the gland is easily palpable from within the mouth. A temporary suture is placed around the duct, proximal and distal to the stone to prevent displacement, and a small incision is made directly over the stone to deliver it into the mouth. When the stone is lodged in the proximal section of the parotid duct the buccal branch of the facial nerve is vulnerable to damage, as it is closely associated with the proximal segment of the duct. After removal of the stone, no suture is required to close the opening in the duct.

SUPERFICIAL PAROTIDECTOMY

Superficial parotidectomy is most commonly undertaken for a lump within the gland. Fine-needle aspiration and MRI can confirm the diagnosis preoperatively, but prior to the excision the malignant potential of the lump is not always known. Adenolymphomas are benign. Pleomorphic adenomas are locally recurrent if excision has been incomplete. One of the rarer salivary gland carcinomas may be suspected preoperatively if growth is rapid or if there is any loss of facial nerve function. However, the majority of malignant parotid tumours do not present with abnormalities of facial nerve function. Pain is also an ominous feature, but can occur in benign disease from haemorrhage into a cystic space.

A nerve monitor, if available, is placed before the initial incision is made, as this will warn the surgeon when the dissection is approaching the facial nerve. The anaesthetist must keep the patient non-paralysed for the device to be effective. The incision should give good access, with well-vascularised flaps and a scar that will lie inconspicuously in skin creases. A suitable cervicofacial incision is shown in Figure 10.14. It is deepened through the platysma until the surface of the parotid fascia is reached, and the anterior skin and platysma flap is elevated to expose the parotid gland with its covering fascia. Care must be taken to avoid injury to the branches of the facial nerve emerging from the anterior border of the gland.

The dissection in a superficial parotidectomy is based on identification of the facial nerve before it enters the gland and, by following the nerve and its branches, removing all tissue superficial to this faciovenous plane. The inferior pole of the parotid is lifted off the surface of the sternocleidomastoid muscle. The greater auricular nerve is found crossing the lateral surface of sternocleidomastoid, and is divided close to the gland. Sternocleidomastoid is then retracted posteriorly and the posterior belly of digastric identified. This is followed up to the mastoid process. The dissection is then carried

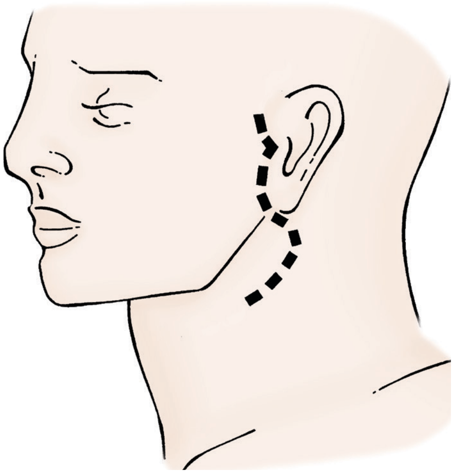

Figure 10.14 *A cervicofacial incision for parotid surgery.*

deeply along the perichondrium of the tragal cartilage, and parotid tissue is separated from the cartilage. The cartilage ends in a 'pointer', which points to the facial nerve, 1 cm medially and inferiorly (Figure 10.15a). A bridge of parotid tissue, overlying the facial nerve, lies between this pointer and the digastric muscle. This can now be elevated to expose the nerve, which is very deep at this point.

Once the nerve has been identified, it is followed forwards into the gland. It runs rapidly towards the surface and account has to be taken of this obliquity during dissection. After about 2 cm it divides into upper and lower divisions. Fine artery forceps are inserted along the superficial surface of the nerve and the glandular tissue lifted forwards to display fine strands of tissue between the nerve and gland, which are cut with scissors. The branches of the upper division are followed until they emerge from the gland. Between each branch of the nerve there will be a bridge of parotid tissue passing between the superficial and deep portions of the gland, which must be divided. No major vessels should be encountered, but ligation of small vessels will be required, especially as diathermy dissection is dangerous in the proximity of the nerve. However, bipolar diathermy to individual small vessels is probably safe. A similar dissection is then performed along the lower division of the facial nerve and its subdivisions. The superficial part of the gland can now be removed, leaving the deep portion of the gland and the parotid duct *in situ*. The whole of the superficial part of the gland does not need to be removed for a lower pole tumour, for which a partial superficial parotidectomy is commonly performed.

As tumours are commonly in the superficial part of the gland, they can be removed by a superficial parotidectomy. However, the deep aspect of a tumour may be exposed by this dissection and great care must be taken to avoid breaching it. Occasionally, a tumour extends deep to the faciovenous plane in the tissue bridge between the branches of the nerve. It is usually possible to retract the nerves with slings and excise the tumour intact without sacrificing nerves. A malignant tumour may invade nerve, and one or more of the branches may have to be sacrificed.

At the end of the dissection, the facial nerve and its branches lie exposed on the surface of the residual gland (Figure10.15b). From the upper division, there should be a temporal branch to the forehead and zygomatic branches,

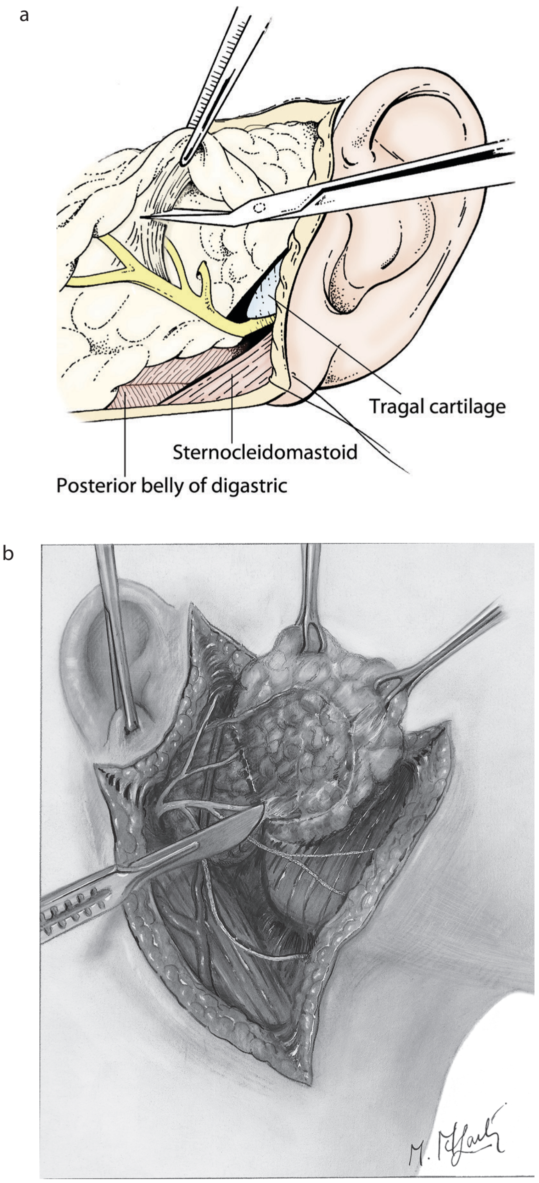

Figure 10.15 *Superficial left parotidectomy. (a) The facial nerve is identified by deep dissection on the surface of the tragal cartilage. The superficial parotid tissue is lifted forwards and the tissue bridges, which pass between branches of the facial nerve to the deep portion of the gland, are divided. (b) The facial nerve and its branches exposed at the end of a right superficial parotidectomy. (From an original drawing in the 1954 edition by Margaret McLarty, a founder member of the Medical Artists' Association of Great Britain.)*

frequently two that cross the zygoma to the corner of the eye and a large buccal branch that runs parallel to the duct and supplies the lower eyelid, nose and upper lip; an additional smaller buccal branch is often seen below the duct. From the lower division, there should be branches to the corner of the mouth and lower lip and to the platysma. If all these branches have been identified and are anatomically intact, the surgeon can be relatively reassured that any immediate postoperative paralysis is no more than a neuropraxia and will recover, often within 48 hours, but may persist longer. A severed nerve can be sutured or, if a portion has been excised, a nerve graft is a possibility, using the greater auricular or sural nerve (see also Chapter 4). The wound is closed over a suction drain with separate closure of the platysma and the skin.

In a superficial parotidectomy the dissection is not infrequently on the deep aspect of the tumour if it is lying on, or extending between, branches of the facial nerve. This has led some surgeons to explore whether a precise local excision as an extracapsular dissection, in contrast to the old-fashioned crude enucleations, is not in fact oncologically inferior to a superficial parotidectomy.[12]

TOTAL PAROTIDECTOMY

A total parotidectomy with sacrifice of the facial nerve may be unavoidable in the excision of a malignant parotid tumour that has extensively invaded the nerve. A facial nerve paralysis is inevitable, but a facial nerve graft (with the greater auricular nerve used to bridge the defect and sutured using the operating microscope) offers the potential for some functional recovery once regrowth of axons has occurred. In most instances it is possible to save some of the facial nerve branches and only sacrifice those that are directly invaded, especially as no survival benefit has been shown for a pre-emptive radical parotidectomy with the sacrifice of uninvolved branches of the facial nerve. Sometimes, a total parotidectomy is combined with excision of the temporomandibular joint, the mastoid process, the external meatus and the overlying soft tissue for a locally aggressive malignant tumour. Unfortunately, such radical surgery is disfiguring and seldom curative.

A total parotidectomy, with preservation of the facial nerve, is occasionally an appropriate operation for a tumour lying wholly, or partially, in the deep portion of the gland. The initial dissection is similar to that for a partial parotidectomy. The plane is developed between the superficial and deep portions of the gland, except in the vicinity of the tumour. Then, depending on the position of the tumour, retraction of either the superior or inferior division of the nerve off the underlying tumour allows access to dissect around the deep portion of the gland. Ligation of the retromandibular vein is necessary, but the external carotid artery can usually be separated from the deep part of the gland unless there is direct tumour invasion. Ligation of the external carotid artery has no sequelae.

The submandibular gland

SURGICAL ANATOMY

The submandibular gland is situated partly below the mandible and partly deep to it. The body of the gland overlaps both bellies of digastric inferiorly. It is enclosed in a loose sheath of deep cervical fascia. The *inferolateral surface* is covered only by platysma and cervical fascia. The *medial surface* lies on, from before backwards, mylohyoid, hyoglossus and the pharyngeal wall. Between the gland and the hyoglossus are the lingual nerve, the submandibular ganglion and the hypoglossal nerve. The *deep part of the gland* is a prolongation extending from its medial surface and lying under cover of mylohyoid. It lies alongside the *submandibular duct,* which also arises from the medial surface of the gland. The duct opens into the mouth on the sublingual papilla at the side of the frenulum of the tongue. The *facial artery* ascends in a deep groove medial to the posterior end of the gland and then turns downwards and laterally between the gland and the mandible to enter the face at the anterior border of masseter. The anterior facial vein descends on the inferolateral surface of the gland.

REMOVAL OF A SUBMANDIBULAR DUCT CALCULUS

A calculus in the duct is palpable intraorally and can be removed very simply under local anaesthesia. Two temporary stay sutures should, however, be placed around the duct on either side of the calculus and retracted upwards. This prevents displacement of the calculus back into the gland (Figure 10.16). The thickened duct is then incised longitudinally over the calculus, which extrudes into the mouth. No attempt to suture the duct is necessary. If the stone is very far

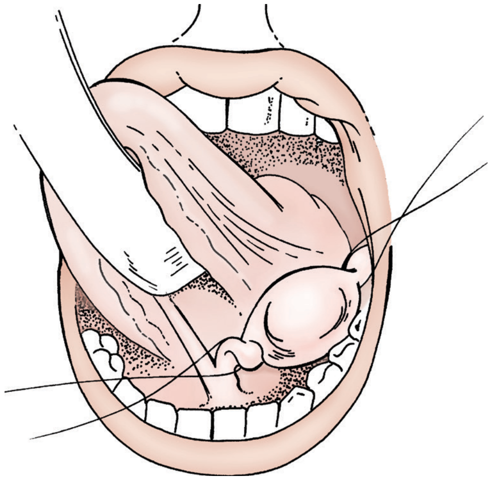

Figure 10.16 *Removal of a left submandibular duct calculus. The tongue is held to the opposite side and a suture placed around the duct, proximal and distal to the calculus, to prevent displacement. An incision is made directly over the calculus.*

back in the duct, then it is usually safer to remove the gland, as attempts at per-oral removal of a posterior calculus risk damage to the lingual nerve.

SUBMANDIBULAR GLAND EXCISION

Submandibular gland excision is advised when the gland is chronically inflamed or is the site of repeated stone formation. It is also a suitable operation for a pleomorphic adenoma. Tumours arising within the submandibular gland are less common than in the parotid, but are more likely to be malignant. Excision for a malignant submandibular salivary tumour may require to be combined with a neck dissection.

Secondary carcinoma of the submandibular lymph nodes is commonly encountered, and may initially be mistaken for a primary salivary gland tumour. Many of these nodes are inseparable from the gland and, if excision is planned, the gland must be removed *en bloc*. However, the correct management of metastatic malignant submandibular glands is that of the underlying pathology. The primary malignancy must be sought and an *en bloc* excision planned if the tumour is still operable.

A submandibular gland excision commences with a horizontal skin crease incision, two finger breadths below the ramus of the mandible, and the incision is deepened down to the body of the gland. A superior flap, consisting of skin, platysma and the investing fascia of the gland, is then raised up to the ramus of the mandible and retracted to expose the whole superficial surface of the gland. The aim is to avoid damaging the marginal mandibular branch of the facial nerve, which lies between the platysma and the fascia, 2 cm below the mandible. It is easily injured if a more superficial upper flap is raised. In a submandibular gland excision for a pleomorphic adenoma, an extracapsular, rather than the subcapsular dissection described above, is recommended.

The facial vein, crossing superficial to the gland, is ligated and divided. Although the facial artery can be dissected out of its groove on the deep surface of the gland, it is simpler to divide and ligate it above and below. It is divided first at the upper border of the gland as it emerges from behind the posterior pole. The gland can now be dissected off the ramus of the mandible and the submental vessels secured. The anterior part of the gland is then dissected backwards off the surfaces of the anterior belly of digastric and the mylohyoid muscles. The posterior border of mylohyoid is identified and retracted anteriorly to display the deep part of the gland and its duct. Inferoposterior retraction of the partially mobilised gland will pull the lingual nerve down in a U-shape, where it is attached to the gland by the submandibular ganglion (Figure 10.17a). This attachment, and the accompanying small vessels, require ligation and division. The hypoglossal nerve may be visible inferiorly (Figure 10.17b), but it is often lying in a slightly deeper plane, protected from the operating field. An absorbable suture is used for ligation of the duct, which is divided as far anteriorly as possible to ensure removal of any small calculi dislodged into the duct. A small bridge of salivary gland tissue may have to be transected at this point if the sublingual gland is continuous with the submandibular gland. The only attachment now is the facial artery, which is ligated and divided for the second time at the lower border of the posterior pole. A short segment of artery is thus removed with the gland, and although this is not always necessary, it makes the dissection easier. A small suction drain to the bed of the gland is brought out posteriorly, and the wound closed with sutures to the platysma followed by skin closure.

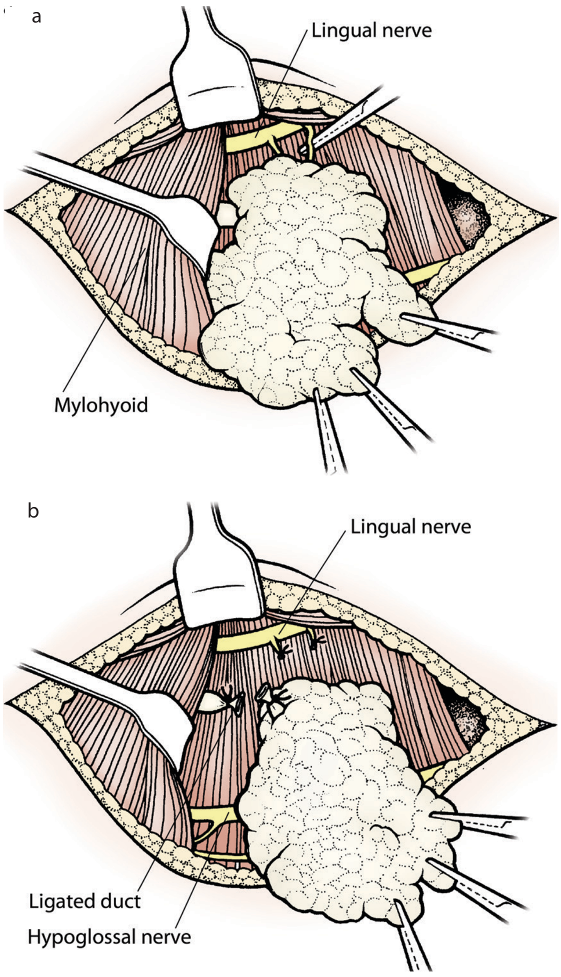

Figure 10.17 *Excision of a left submandibular gland. (a) The facial artery has been divided above the gland and the superficial portion of the gland has been dissected off mylohyoid, which is now retracted forwards. The tented lingual nerve is visible. (b) The attachments to the lingual nerve have been divided, and the submandibular duct is ligated. The hypoglossal nerve is visible inferiorly.*

SURGERY OF THE LARYNX, PHARYNX AND TRACHEA

Only the general surgeon who is unable to refer patients to a specialist will expect to operate on these structures, all of which lie within the province of the ENT head and neck surgeon.

Tracheostomy

This was once a common operation for life-threatening obstruction of the upper airway. The situation is now usually more satisfactorily managed by emergency endotracheal intubation, and it is only in exceptional circumstances that this is not possible. Endotracheal intubation is the standard method for control of a patient's airway, and is used both for the patient who is deeply unconscious with no gag reflex to protect the lower airway and for the patient requiring ventilatory support. Long-term intubation of the larynx is damaging, however, and a decision regarding the need to convert to a tracheostomy should usually be made if the patient cannot be extubated within 2 weeks. This conversion to a tracheostomy is now commonly performed percutaneously in the intensive care unit by anaesthetists using specially designed kits. Most other tracheostomies are fashioned by the head and neck surgeons at the completion of a major resection. It is therefore now rare for a general surgeon working in a hospital with ENT surgeons and a well-developed anaesthetic service to undertake a tracheostomy either electively or in an emergency.

Anaesthesia

Ideal operative conditions include a general anaesthetic with the airway secured with an endotracheal tube. However, when a general surgeon has to perform a tracheostomy it will almost always be in an emergency, in suboptimal conditions and on an unanaesthetised patient with no airway protection. In the unconscious, deeply cyanosed patient no anaesthesia is needed and no further delay is justified. In the conscious distressed patient with partial airway obstruction, lidocaine with adrenaline is infiltrated deep to the proposed skin incision. In the developing world, the commonest scenario is a distressed baby or toddler with increasing airway obstruction from diphtheria and no skilled anaesthetic personnel or facilities available. Secure restraint of the child is mandatory. The child is wrapped in a sheet so that the arms are held firmly, and one assistant holds the child's body. A second assistant holds the child's head, comforts the child, maintains oxygen delivery and aspirates secretions from the upper airway.

Operative procedure

A transverse incision midway between the cricoid cartilage and the suprasternal notch is deepened through platysma (Figure 10.18a). In an emergency a vertical incision is acceptable. The strap muscles are separated in the midline and the trachea palpated, with the overlying thyroid isthmus, under the cervical fascia. The thyroid isthmus is freed from the trachea, divided between clamps and the ends oversewn with an absorbable suture (Figure 10.18b). Inferior thyroid veins may cross the operative field and require ligation and division. The cricoid and upper tracheal rings are now easily identified.

The inexperienced operator will tend to drift cranially as, in the adult, the trachea becomes progressively deeper as it is traced distally and, in the child, the innominate vein and the thymus may lie anterior to the trachea above the suprasternal notch. In addition, the apical pleura and the obstructed lungs will bulge up into the wound. It is important, however, that the tracheostomy is made at the level of the second to fourth tracheal ring, as a more proximal tracheostomy damages the cricoid cartilage and a subglottic stenosis may follow. The damage may be direct mechanical damage from a tracheostomy performed through the cricoid cartilage itself, but the cricoid can also be damaged by a perichondritis from an adjacent tracheostomy through the first tracheal ring.

A vertical midline incision in the trachea will allow insertion of the tube in a child or young adult. This is the technique least likely to cause a tracheal stenosis or a failure of closure of a temporary tracheostomy. However, in an older

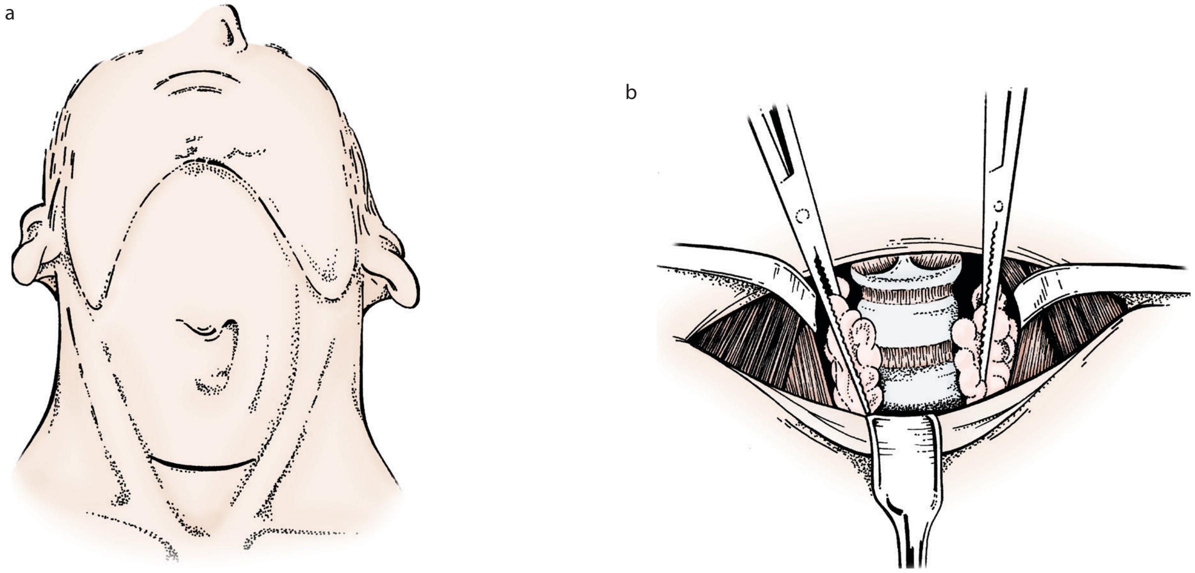

Figure 10.18 *Tracheostomy. (a) A horizontal incision leaves a less conspicuous scar. (b) The thyroid isthmus is divided to expose the trachea.*

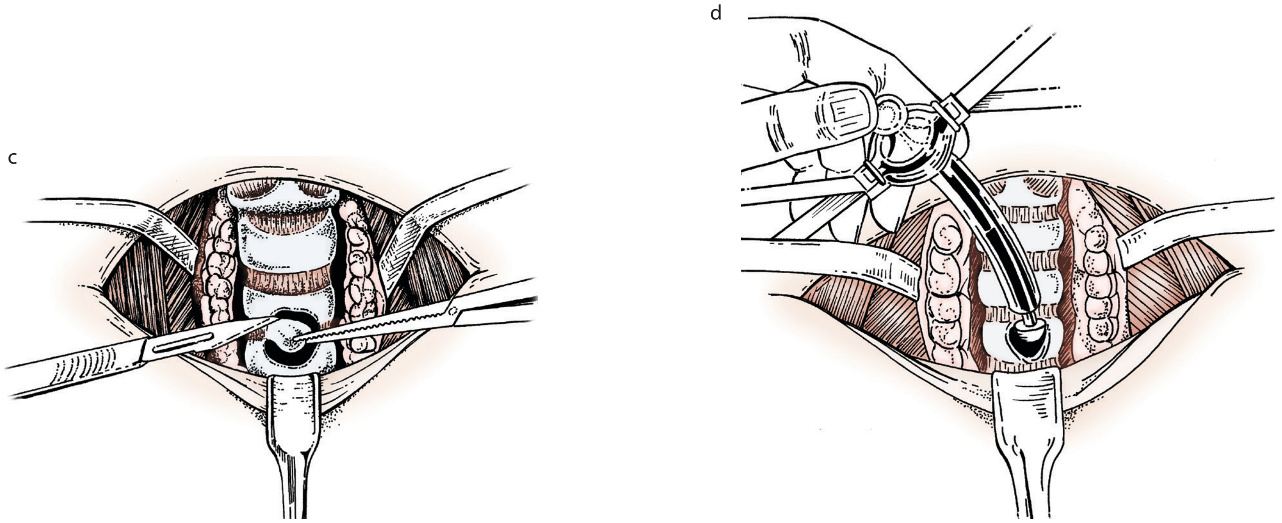

Figure 10.18 (*continued*) *(c) A disc of a calcified tracheal ring can be excised. (d) The tracheostomy tube is inserted.*

patient with calcification of the trachea, it is usually more satisfactory to remove a small disc of the second or, preferably, the third ring (Figure 10.18c). At this point the anaesthetist is advised to withdraw the endotracheal tube (if the procedure is being performed under general anaesthesia). Blood is aspirated from the trachea, the tracheostomy tube is inserted and the wound closed (Figure 10.18d). This should only be a loose closure or surgical emphysema may be troublesome. This initial tube should be sewn and taped in place because if it becomes displaced, replacement in the first 72 hours before a track has been established is difficult.

PERCUTANEOUS TRACHEOSTOMY

Percutaneous tracheostomy is performed through an initial small skin incision. A needle with cannula is introduced into the trachea, the needle removed and a guide wire inserted through the cannula, which is in turn withdrawn. After the track has been dilated by forceps or by serial plastic dilators passed over the guide wire, the tracheostomy tube is inserted.

Branchial cysts and fistulae

These are congenital abnormalities associated with the failure of obliteration of branchial clefts. A branchial cyst presents most often in late childhood or early adult life as a deep cystic swelling at the anterior border of the sternocleidomastoid, between its upper one-third and lower two-thirds. A branchial fistula is apparent at birth as an external opening near the anterior border of sternocleidomastoid, close to its distal insertion. The internal opening is usually in the tonsillar fossa.

A skin crease incision over a branchial cyst affords adequate access for its excision (Figure 10.19a). The incision through skin and platysma should be at least 2 cm below the angle of the jaw in order to avoid the marginal mandibular branch of the facial nerve. The deep cervical fascia is incised along the anterior border of sternocleidomastoid. The cyst can then be carefully enucleated, but a search should be made for a deep extension. If present, this track will pass between the internal and external carotid arteries to the pharynx in the region of the tonsillar fossa, and must be excised (Figure 10.19c).

A branchial fistula will frequently require two incisions, as the first elliptical incision to excise the external opening will be too low for higher access (Figure 10.19b). The track is often incomplete and ends blindly, but again the surgeon must be prepared to follow the track between the carotids if necessary. Branchial cyst and fistula surgery should not, therefore, be approached lightly by a surgeon infrequently performing neck surgery.

Pharyngeal pouch

The common form of pharyngeal pouch is an acquired posterior diverticulum between thyro- and cricopharyngeus, in which food becomes trapped. Failure of relaxation of cricopharyngeus is thought to be the underlying pathology. The fundus of the pouch lies alongside the oesophagus, which is then compressed by the pouch (Figure 10.20).

Endoscopic stapling procedures are increasingly popular in expert hands but, if an open technique is required, the pouch is packed with gauze at a preliminary endoscopy to facilitate its identification. A standard cervical approach to the oesophagus (see below) brings the dissection onto the gauze-filled pouch lying behind the oesophagus, from which it must be separated. The plane around the fundus of the pouch is then followed up to its neck and the neck opened. A finger is inserted through the neck of the sac down into the oesophagus, putting the cricopharyngeus on stretch. A posterior vertical 4 cm myotomy of this muscle is then performed. The recurrent laryngeal nerves lie laterally and should not be

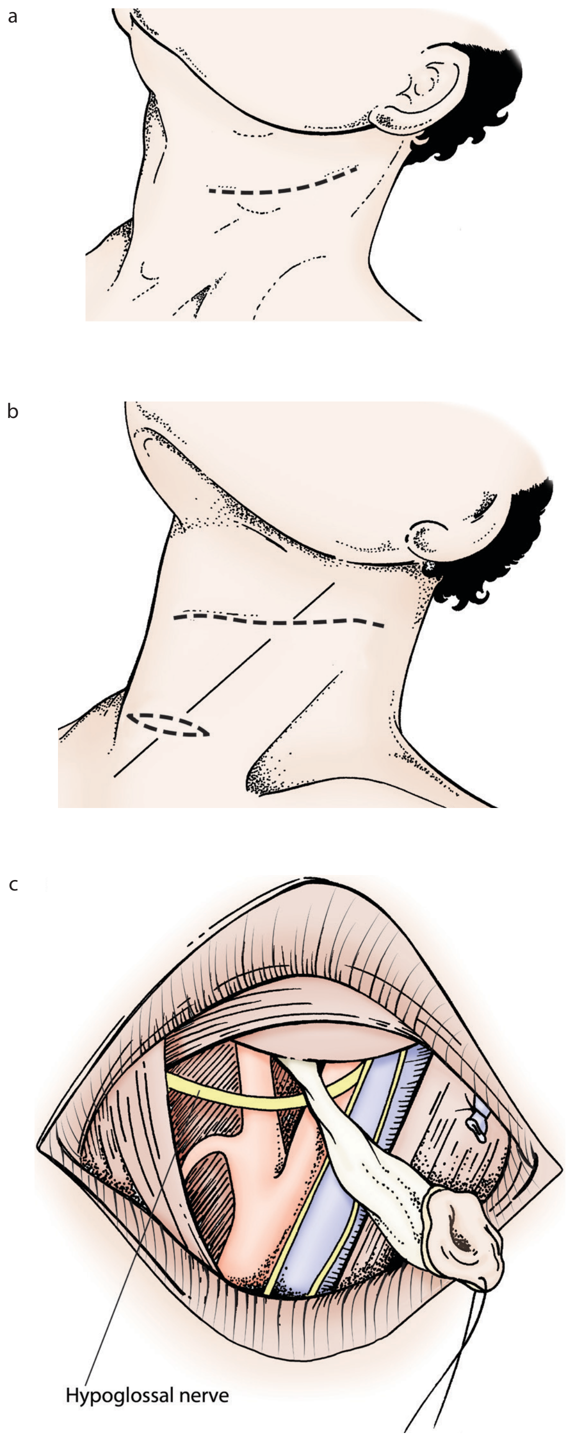

Figure 10.19 *Branchial cyst and fistula. (a) A single incision over a cyst is usually adequate. (b) The opening of a branchial fistula must be circumscribed by an elliptical incision, and the dissection of the fistula is commenced through this incision. Access for the proximal dissection will be inadequate, and a second higher incision as marked will be necessary. (c) The fistula track passes between the carotid arteries to the tonsillar fossa.*

endangered if the myotomy is performed in the midline posteriorly. The pharyngeal wall at the neck of the sac is closed and a drain is placed adjacent to the closure.

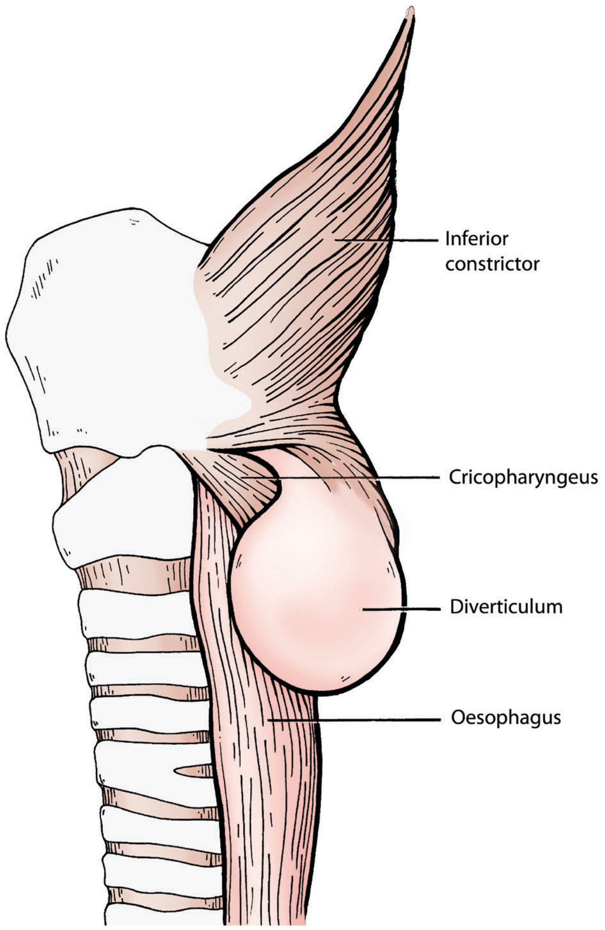

Figure 10.20 *The neck of a pharyngeal pouch is just above the cricopharyngeus, but the fundus compresses the upper oesophagus.*

Surgery for malignancy of the larynx, pharynx and trachea

Much of the radical surgery for cancers of the larynx and hypopharynx has now been centralised in specialist units. Close cooperation is essential between surgeon, radiotherapist and oncologist to plan the optimum treatment. Accurate preoperative staging is important. Radical mutilating surgery is justified if it offers the best chance of cure or of local control of the disease, but must not be undertaken when it can achieve neither and will merely add to the patient's distress. Postoperatively, the patient will need skilled rehabilitation and speech therapy. Regional centres specialising in this work will achieve better results, and most general head and neck surgeons in the UK are no longer performing the occasional major resection for cancer. This work is now totally outside the field of the general surgeon.[13] An isolated general surgeon in a developing country without access to referral facilities is unlikely to be in a position to undertake such an operation, and is even less likely to be able to offer the patient a reasonable expectation of a cure with good rehabilitation.

General surgeons should, however, be aware of the principles of these resections, if only to understand what has been done in a patient who is subsequently admitted under their care with related or unrelated pathology.

LARYNGECTOMY

A horizontal incision is made through skin and platysma. The subsequent dissection will depend on whether the laryngectomy is to be combined with a neck dissection. The thyroid lobe on the side of the tumour is commonly removed with the larynx, and the strap muscles on this side are divided at their lower end and excised as part of the specimen. Thus, the larynx is mobilised laterally by a thyroid lobectomy dissection on one side and through the plane between the thyroid gland and the trachea on the other. Posteriorly, it must be separated from the oesophagus. Inferiorly, the trachea is transected and the distal end mobilised so that it can be brought out as an end tracheostomy, which is sutured to the skin. Superiorly, the suprahyoid muscles and the stylohyoid ligaments are divided and the hyoid bone is removed with the specimen. Removal of the larynx then leaves an anterior defect in the pharynx, which is closed. Various forms of partial laryngectomy with preservation of speech have also been developed, but these procedures are limited to specialised head and neck centres.

LARYNGOPHARYNGECTOMY

This more extensive resection is usually performed through an apron or transverse incision. One or both lobes of the thyroid are often included in the specimen and the resection is commonly combined with a neck dissection. The tracheostomy is established early in the procedure. The initial dissection is similar to that for a laryngectomy, but laterally the dissection is carried posteriorly, down to the prevertebral fascia, and the pharynx is drawn forwards as part of the resection specimen. Superiorly, the resection is above the hyoid, and the base of the tongue is transected leaving a hole into the oral cavity. When the operation is combined with an oesophagectomy, reconstruction is usually with the stomach, pulled up through the posterior mediastinum after intra-abdominal mobilisation (see also Chapters 17 and 18). If only the proximal cervical oesophagus is included in the resected specimen, a free jejunal flap can be utilised as an alternative for reconstruction. This involves a microvascular anastomosis of the mesenteric pedicle of the jejunum onto the recipient vessels in the neck, and anastomosis of the jejunal tube proximally and distally to bridge the gap from the pharyngeal resection. If microsurgical skill is not available, then a tubularised pectoralis major flap can be used. This flap is a myocutaneous flap with a good blood supply and is illustrated in Figure 11.11 (p. 198).

SURGERY OF THE OESOPHAGUS

Surgery of the oesophagus is covered in greater detail in Chapters 17 and 18, which relate to the upper gastrointestinal tract. However, the approach to the cervical oesophagus is described below. Direct surgical access may occasionally be required for an impacted foreign body that cannot be removed endoscopically, for the open repair of a pharyngeal pouch or for the repair of trauma that is too severe to be managed conservatively. More commonly it is required for an oesophagostomy or an oesophageal anastomosis. A cervical oesophageal anastomosis after oesophagectomy is a safer anastomosis if it leaks than one within the thorax, and therefore a more radical oesophagectomy is sometimes preferred in order to bring the anastomosis up into the neck. On other occasions a more proximal tumour itself necessitates a cervical anastomosis.

Oesophagostomy is a permanent or temporary end stoma of the oesophagus. It allows drainage of swallowed saliva, preventing it from entering an area of oesophageal breakdown or, when there is a complete obstruction, pooling above it with threat to the airway. With the improvement in oesophageal stents, oesophagostomy is seldom necessary in malignant obstruction, but it still has a role in patients who have had a major failure of an oesophageal reconstruction or oesophageal destruction from caustic burns. In addition, such patients will require a feeding gastrostomy and drainage of the posterior mediastinal sepsis. Reconstruction can then be postponed until local conditions in the mediastinum have improved and the patient has recovered good physiological and nutritional status.

An oesophagostomy can also be a temporary solution in a long-segment oesophageal atresia that cannot be reconstructed in the neonatal period. It prevents saliva from entering the bronchial tree and also allows the baby to develop feeding skills while gaining weight on gastrostomy feeding, prior to major reconstructive surgery (see Chapter 18).

CERVICAL APPROACH TO THE OESOPHAGUS

A transverse skin crease incision at the anterior border of sternocleidomastoid is made through skin and platysma. The height of this incision will vary according to the level of oesophagus to which access is required, but the level of the cricoid cartilage is most often appropriate. The deep cervical fascia is then incised along the anterior border of sternocleidomastoid, which is retracted laterally. The thyroid is retracted medially and the middle thyroid veins and omohyoid are divided. The carotid sheath is retracted laterally and the inferior thyroid artery ligated and divided. This plane between the thyroid and the carotid sheath takes the surgeon down to the prevertebral fascia, and the dissection should be safely lateral to the recurrent laryngeal nerve. The nerve is, however, still in danger in its groove between the trachea and the oesophagus as the oesophagus is mobilised. It is therefore safest to identify the recurrent laryngeal nerve as it crosses the medial end of the inferior thyroid artery. Once identified, it can then be followed both up and down and safeguarded from injury.

The vertebral bodies of the cervical column can be approached anteriorly by using the same dissection as that described above for the oesophagus.

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11

SURGERY OF THE FACE AND JAWS

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In the developed world a general surgeon will perform only relatively minor facial surgery, but it is still important that the particular challenges of surgery on the face are understood. Facial lacerations will require suturing and skin lesions will be excised for histology, but more major surgery will generally be passed on to the relevant specialist, whether a head and neck or plastic surgeon, an ophthalmologist or a maxillofacial surgeon. However, some general surgeons may be unable to transfer patients and are thus forced to offer limited surgical services across all these specialities.

WOUNDS

The principles of surgery on the skin are discussed in Chapter 2 and these are of particular importance in the face, where it is so important to reduce disfigurement to a minimum and maintain function. Most cases of extensive injury will require the attention of a plastic surgeon who should, if possible, carry out the initial repair. However, if specialist help is not available, the surgeon carrying out the initial repair must do nothing that will make later reconstruction more difficult. The main concern should be to avoid unnecessary scar formation by careful cleansing of the wound, debridement and accurate repair of the tissues in layers with fine sutures.[1]

Exploration and debridement of the wound

Because of the extensive vascularity of the face, primary suturing is usually a safe procedure, even for injuries such as dog bites. When there has been contamination, appropriate tetanus and antibiotic prophylaxis should be given. Irregular lacerated wounds should be trimmed with a sharp knife or fine scissors. Formal excision of a wound is usually unnecessary and can result in unjustifiable sacrifice of healthy tissue. It is important, however, to remove all ingrained dirt, as only in this way can one avoid leaving disfiguring pigmented scars, which are difficult to adequately remove later. Scrubbing with a brush under general anaesthesia may be the only way of doing this effectively, especially for a large area of superficial abrasion with a 'gravel rash'.

Wounds involving deeper structures

Divided facial muscles should be approximated before skin closure. In the case of a wound involving the whole thickness of the lip or cheek, the mucous membrane, muscles and skin should be sutured separately. The mucous membrane is sutured first. In wounds of the eyelid, the tarsal plate must be identified and sutured to reduce the risk of distorting the margins of the eyelids. Careful attention must be paid to the possibility of damage to the canthal ligament and the nasolacrimal ducts in wounds near the inner canthus, and expert help should be sought if injury to these structures cannot be excluded. Vision in the underlying eye must be checked, and the possibility of a penetrating injury to the eyeball or into the orbit or cranium must also be considered.

Damage to the parotid duct or facial nerve should be suspected in any laceration of the cheek that crosses the path of these structures. The surgeon should be alerted to damage to branches of the facial nerve by partial paralysis of the facial muscles, but this may be difficult to detect when there is significant swelling. Divided branches distal to a perpendicular line drawn down from the lateral canthus rarely need reapproximation, as the stump of the nerve tends to reinnervate directly the muscles of facial expression. When a laceration overlies the course of the parotid duct, damage should be actively sought by massaging the parotid gland and looking for salivary seepage in the wound. If any of these fine structures requires repair, this should ideally be undertaken at the initial operation by someone who is experienced in the use of an operating microscope. It may be impossible to identify and repair fine and complex structures at a secondary operation, and the importance of early involvement of the relevant specialist cannot be overstressed.

Wounds with skin loss

Since the facial skin is so elastic, skin loss is often more apparent than real, with the wound gaping in a frightening manner because of muscle retraction and oedema. Often it will be found at surgery that there is little or no tissue missing once the 'jigsaw puzzle' has been completed. When there is significant tissue loss, skilled reconstructive surgical expertise should be sought at the primary repair. However, flap repairs should not, in general, be attempted as a primary procedure in a facial injury. A full-thickness graft can be applied if conditions are suitable, and even a temporary, thin partial-thickness skin graft over a denuded area will reduce contractural scarring. Skin graft 'take' onto denuded bone can be successful if the outer cortical plate of the bone is first perforated. When the whole thickness of the lip, cheek or nose is missing, skin should be united to mucous membrane around the margins of the defect. The elimination of a raw area allows rapid healing with minimal distortion and scarring, and thus facilitates definitive reconstruction.[1]

Skin sutures

Accurate apposition without tension is important, and particular care must be taken at the vermilion border of the lip otherwise an ugly step will be apparent. Fine needles and fine suture material that excite minimal tissue reaction should be used: 5/0 or 6/0 Prolene™ is suitable for an interrupted suture and 4/0 or 5/0 Prolene™ for a subcuticular suture. Interrupted sutures should be positioned close to the skin edges to reduce scarring, but they should also approximate the underlying fat (Figure 11.1) and thus avoid the necessity for additional subcutaneous sutures, which inevitably cause further tissue reaction. If a subcutaneous suture is necessary, it should not be closer than 5 mm from the skin. Overtightening of sutures, which strangulates tissue, must be avoided. Interrupted sutures should ideally be removed after 3–5 days to prevent additional scarring from the sutures. The wound, however, should be supported for a further 5–10 days with strips of adhesive skin tape (see Chapter 2).

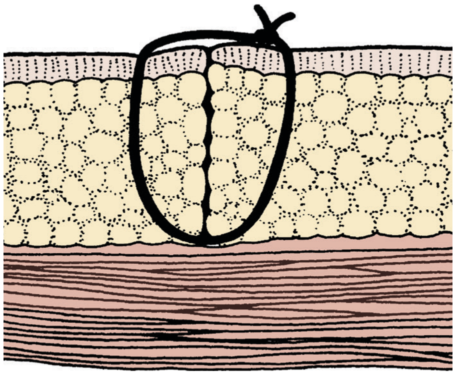

Figure 11.1 *Accurate apposition of skin and subcutaneous fat without tension minimises scarring. The sutures are placed close to the skin edges.*

FRACTURES OF THE FACIAL SKELETON AND THE JAWS

Treatment of these fractures is often complex and should only be undertaken by general surgeons if they are working in remote areas without access to maxillofacial expertise.

Fractures of the mandible

Some minor undisplaced fractures only require analgesia and antibiotics, without any fixation. However, in a bilateral fracture, the downward displacement of the anterior fragment may be considerable from the combined forces of gravity and the action of the muscles of the floor of the mouth. The fracture must be reduced accurately and fixed to allow bony union in a good position to restore dental occlusion. Despite the swelling, there is seldom any impairment of the airway in a conscious patient.

The injuries seen in war often include fractures of the maxilla and severe soft tissue damage to the face. (A publication from WW II documents 1,000 cases from the Italian and North African campaign alone.[2]) There may also be associated missile injuries to the pharynx, orbit or brain. Principles of management of these severe injuries consist of initial protection of the airway and arrest of haemorrhage. Endotracheal intubation or tracheostomy may be necessary, and cricothyroid puncture may be a temporary life-saving procedure.[3] (See also Chapter 10.)

RIGID FIXATION

Rigid fixation of a mandibular fracture can be made between the teeth on either side of the fracture or to the teeth of the opposing jaw. Alternatively, the fracture can be exposed via the gingivolabial sulcus for fixation. Any method of direct fixation should remain *in situ* for a minimum of 6 weeks.

Interdental 'eyelet' wiring

This requires healthy stable teeth adjacent to the fracture (Figures 11.2a and b). An *arch bar* of malleable material can also be fixed against the outer surface of the teeth on either side of the fracture, thus offering some additional support. Although a satisfactory method of stabilising a dentoalveolar fracture and allowing movement of the jaw, this approach provides insufficient fixation for any major mandibular fracture. It is therefore also necessary to wire the lower teeth to the upper teeth to provide adequate stabilisation of the fracture (Figure 11.2c). This is, however, at the expense of any jaw movement. Feeding and oral hygiene are difficult but, more importantly, inhalation of vomit can prove fatal. Wire cutters must be immediately available for this emergency.

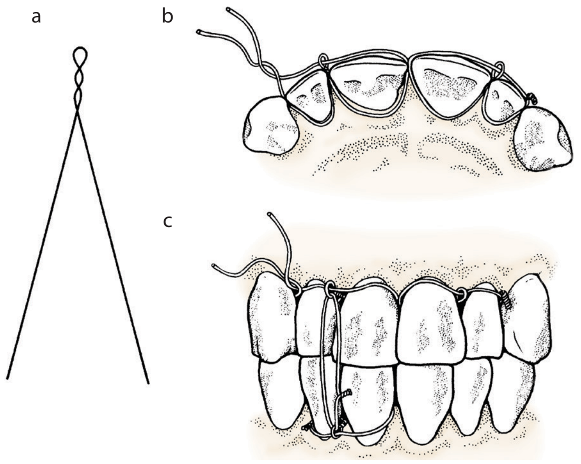

Figure 11.2 *(a) Stainless steel wire (0.4 mm or gauge 26–32) is twisted to make eyelets, which can be passed between the teeth. (b) Further wires are linked by passing them through the eyelets. (c) Wires secured to teeth on either side of the fracture can then be linked either between the upper and lower teeth or to a splint.*

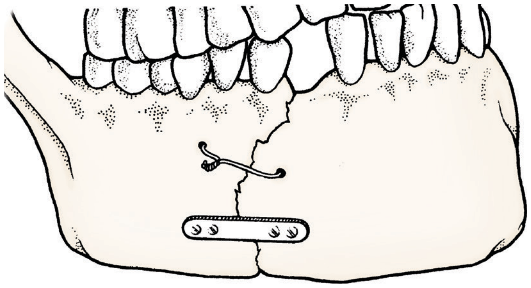

Figure 11.3 *Two methods of open fixation of a mandibular fracture.*

Open fixation

The main advantage of open fixation is that an accurate reduction can be rigidly supported while still allowing the patient jaw movement in the immediate postoperative period (Figure 11.3). Most fractures of the mandible are compound and surgical access has further potential to contaminate the fracture site with oral bacteria. Despite this, open fixation seldom results in infective complications, but should nevertheless be covered with appropriate antibiotics.

Fractures of the maxilla

Injuries involving the alveolar segment of the maxilla can be stabilised with interdental wiring or with a variety of dental splints. Those occurring as part of a complicated middle third facial fracture may be associated with damage to adjacent structures such as the orbit, nasolacrimal apparatus, nose and ethmoid region. An associated fracture of the anterior cranial fossa may be complicated by cerebrospinal fluid rhinorrhoea. A general surgeon operating on such an injury in a remote or conflict setting can only follow some cardinal principles:

- Adequate exposure with a protected airway.
- Recognition that the bony fragments must be reduced and stabilised by wiring, pinning or plating before any soft tissue reconstruction begins.
- In fractures involving the ethmoid region, the attachments of the medial canthal ligaments may have been disrupted. Primary repair is important as secondary revision is fraught with difficulty.
- In patients with combined maxillary and mandibular injuries, the mandible should be reduced and fixed first, and the maxilla subsequently reduced to it, so that anteroposterior projection of the middle third of the face can be restored.

Fractures of the zygoma

Fractures of the zygoma may be easily missed in the presence of severe soft tissue swelling of the face. The zygomatic bone is usually separated from its normal attachments and displaced downwards. Examination may reveal a palpable ‘step’ deformity in the orbital margin, and the fracture is then confirmed with an occipitomental X-ray. Zygomatic fractures are often associated with additional damage to the facial skeleton, in particular blow-out fractures of the orbital floor. Skilled reduction and fixation are mandatory if a good functional and cosmetic result is to be achieved. Inadequate reduction, with resultant displacement of the eyeball, is difficult to resolve later.

An isolated zygomatic fracture can be levered back into position. A small incision is made in the temporal region inside the hairline and extended down through the temporalis fascia to display the temporalis muscle fibres. An instrument, preferably a Bristow elevator, is then inserted through the incision and directed downwards beneath the zygomatic arch. The elevator is then lifted bodily forwards and outwards, and the zygoma is reduced, usually with an audible click. The technique of using a rolled-up swab as a fulcrum and levering the zygoma back into position exerts considerable pressure on the cranium, and iatrogenic fractures of the temporal bone can occur. If the fracture cannot be reduced or is unstable, an open reduction with exploration of the orbital floor and direct wiring at several sites may be needed.

Fractures of the nasal bones

Nasal fractures are commonly displaced, but this is not always apparent until the swelling subsides. Without reduction, the asymmetry and loss of normal contours can leave a patient with an unacceptable cosmetic result and, in addition, a deviation of the septum can result in an inadequate airway on one side. Reduction of the fracture under local anaesthesia by digital manipulation should be carried out before healing is too advanced, but it is often easier when some of the swelling has subsided. Around 10 days after injury is a satisfactory compromise. After 3 weeks it is normally no longer possible to manipulate the nasal bones.

A post-traumatic septal haematoma should be sought and drained otherwise it can lead to necrosis of the underlying cartilage and subsequent septal perforation.

INFECTIONS OF THE FACE

Surgical drainage of infections is seldom necessary where there is early access to antibiotic treatment. However, general surgeons practising in areas where many patients are remote from primary healthcare facilities may still have to operate for these conditions.

Soft tissue infections

These infections can occasionally lead to major tissue destruction. *Cancrum oris*, which is encountered almost exclusively in malnourished children in the developing world, is a spreading necrotising synergistic infection. Treatment is with penicillin and metronidazole, nutritional support and excision of necrotic tissue. The final full-thickness tissue loss extending from the mouth into the cheek will require skilled surgical reconstruction, but should ideally be deferred for 3–6 months. Sometimes these children can be transferred to a regional plastic surgical centre or be treated by a plastic surgical team on a short-term medical mission.[4] Unfortunately, this is a disease that occurs in areas of the world least served by specialist care. A general surgeon unable to transfer a child might be able to improve the situation with one of the flaps described later in this chapter, or even a waltzing flap (see Figure 2.23, p. 30).[5]

Infection in the orbit

Orbital infection may be secondary to a sinus infection or a penetrating injury. Pus behind the eye is under pressure and the patient has severe pain, proptosis and some unilateral visual impairment. Pus can be drained by an incision in the sclerotarsal fold. Pus within the orbit secondary to an ethmoid sinusitis is most satisfactorily drained by a Lynch–Howarth incision, as illustrated in Figure 11.7. An eye destroyed by panophthalmitis and filled with pus must be enucleated or eviscerated (see below).

Sinus infections

An infected sinus will occasionally fail to settle on antibiotic therapy. The sinus is filled with pus, which is unable to drain through an obstructed outlet, and surgical intervention becomes necessary. The maxillary sinus can be entered transnasally and washed out under local anaesthesia. A trocar is advanced through the bony lateral wall of the nasal cavity under the inferior turbinate, aiming for the tragus.

Infections of dental origin

Dental sepsis will commonly settle with antibiotic therapy, but if pus has formed, then drainage is required. An *alveolar abscess* around the root of a tooth subsides rapidly after the offending tooth is extracted. A *subperiosteal abscess* may follow an untreated alveolar abscess. The pus may be on the external or internal surface of the bone and is drained into the mouth by an incision in the mucoperiosteum parallel to the alveolar margin. Care must be taken in the region of the lower premolar teeth to avoid damage to the mental nerve. *Ludwig's angina* is a bilateral cellulitis within the submental and submandibular triangles, associated with gross swelling. It is usually secondary to a dental infection. Drainage of pus or, more commonly, an incision simply to decompress may be necessary and a pre-emptive tracheostomy may have to be considered in such patients. Drainage of the submental space is shown in Figure 11.4.

Osteomyelitis of the jaws

Osteomyelitis of the maxilla or mandible is extremely rare in patients who have access to antibiotic treatment for the primary dental or sinus infection. Drainage of pus from the bone or removal of sequestra will leave less scarring if it is possible to approach from within the mouth.

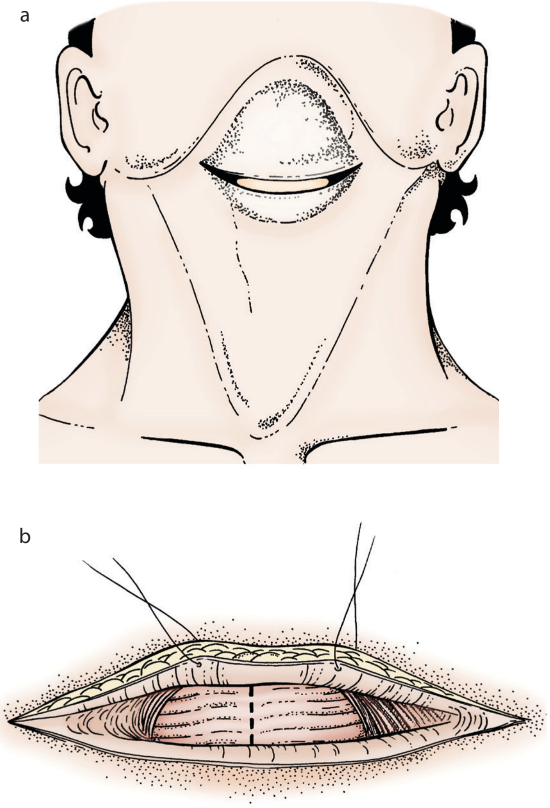

Figure 11.4 *Pus in the submental space may be deep to the mylohyoid muscle. (a) The transverse skin incision; (b) the vertical incision in mylohyoid.*

Peritonsillar abscess (quinsy)

A peritonsillar abscess requires drainage of pus by an incision over the most prominent part of the swelling (under local anaesthesia in adults). The swelling is first aspirated with a needle to confirm the presence of pus. A mucosal incision is then made, followed by gentle exploration of the abscess cavity with sinus forceps. Any deep incision with a scalpel can result in torrential haemorrhage.

Retropharyngeal abscess

A retrophrayngeal abscess lies between the pharynx and the vertebral column in the retropharyngeal space, which extends from the base of the skull to the posterior mediastinum. The abscess is visible as a bulging of the posterior oropharynx. In childhood this abscess is seldom tuberculous and can be drained through the mouth; airway protection from inhalation is crucial. A tuberculous retropharyngeal abscess in an adult, secondary to cervical tuberculosis, is better approached from the neck (see Chapter 10).

Acute mastoiditis

An acute mastoid infection that fails to resolve on antibiotic therapy will still occasionally require emergency release of pus from the mastoid cavity in order to prevent intracranial extension of the infection. A postauricular incision is made 2 cm behind the post-aural crease directly onto the bone of the mastoid. The periosteum of the mastoid is elevated until the anterior edge of the mastoid and the superior wall of the external meatus are seen. Imaginary tangents are drawn from these landmarks and they intersect on the mastoid. The area bounded by these tangents and the external meatus is called Macewan's triangle (Figure 11.5). Entry into the mastoid should be through this triangle to minimise danger to the facial nerve and the dura. Entry through the bone can be by drill or by chisel. A general surgeon forced to operate on this condition can be content with the release of pus and the placement of a drain for up to 48 hours. Further exploration of the mastoid cavity, the underlying dura or of a thrombosed sigmoid sinus is likely to cause more harm than good.

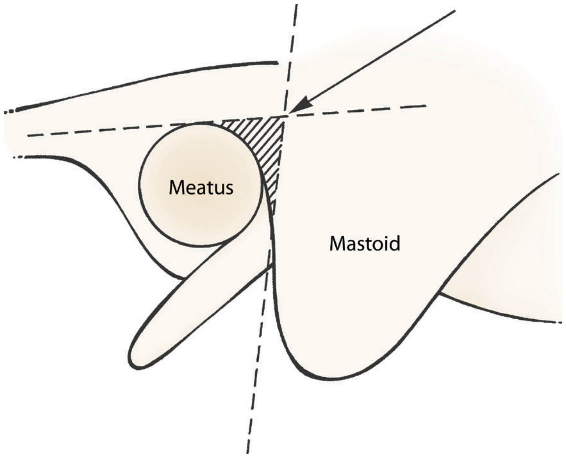

Figure 11.5 *Macewan's triangle. The periosteum is elevated from the bone until the anterior border of the mastoid and superior wall of the meatus can be identified as landmarks. A horizontal tangent, from the superior border of the meatus and continuous with the zygomatic arch, meets a vertical tangent, taken from the anterior border of the mastoid, to delineate the shaded triangle through which the mastoid cavity can be most safely approached.*

SURGERY AROUND THE EYE

Periorbital skin lesions

Removal of a skin lesion from immediately below the lower lid, followed by primary closure, can drag the lower lid down and cause it to be lifted away from the eyeball and even to evert (Figure 11.6). This *ectropion* will result in a watering eye as the inferior punctum is no longer in contact with the eye. This situation can be avoided by a full-thickness graft (see Chapter 2). Direct damage can also occur to the nasolacrimal apparatus at the inner canthus. Periorbital skin lesions should be carefully assessed preoperatively and referral to an ophthalmologist or a plastic surgeon for the initial operation should always be considered.

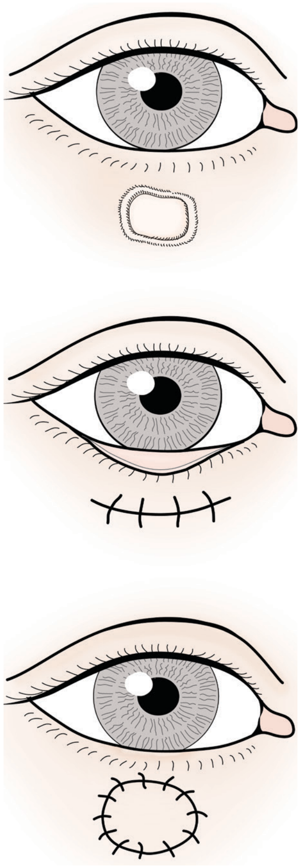

Figure 11.6 *A skin tumour beneath the eye can distort the lower lid if it is excised as an ellipse and closed as a linear wound. A circular excision and a Wolfe graft produce a more satisfactory result.*

External angular dermoids

These are congenital cystic swellings, usually at the superolateral margins of the orbit, which enlarge with age. They most often present in early to mid childhood. Excision is normally straightforward, but they may be deeply indented into the outer table of the skull. The occasional dermoid has no bony separation from the dura, a situation of which the surgeon would wish to be aware prior to operation. It is therefore recommended that dermoids that feel fixed to the bone and dermoids that extend under the supraorbital ridge are examined by preoperative ultrasound where possible or, alternatively, an X-ray to confirm an intact inner table of skull. Complete removal of the intact cyst is important because if it is ruptured during the surgery, postoperative inflammation can be intense. The incision should be just below, or occasionally above, and parallel to the eyebrow (Figure 11.7). The temptation to hide the incision within an eyebrow is mistaken, as hair follicle scarring results in deformity of the eyebrow.

Surgery of the eyelids

This fine surgery should normally be passed by a general surgeon to either an ophthalmologist or a plastic surgeon. However, some remote general surgeons may be able to offer some simple but effective surgery that can preserve sight in the underlying eye.

Eyelid repair

Lid repair after trauma can be successfully achieved by following general principles of accurate apposition of fine tissues, with particular care taken to achieve accuracy at the lid margins. The junction between the eyelid skin and the tarsal conjunctiva (the grey line) should be identified and sutured very accurately to avoid a step in the eyelid margin. The tarsal plate is repaired with fine, absorbable sutures, such as 6/0 Vicryl™, placed so that the knots do not irritate the cornea. The skin is then closed with fine, non-absorbable sutures. If, however, a canaliculus is lacerated, repair will be very difficult without the magnification of an operating microscope. When damage is suspected, it is confirmed with a lacrimal probe and repair is performed around a fine silicone tube passed through the lid punctum, across the divided area in the laceration and on through the distal duct into the nasal cavity. The silicone tube is left *in situ* for 3–6 months.

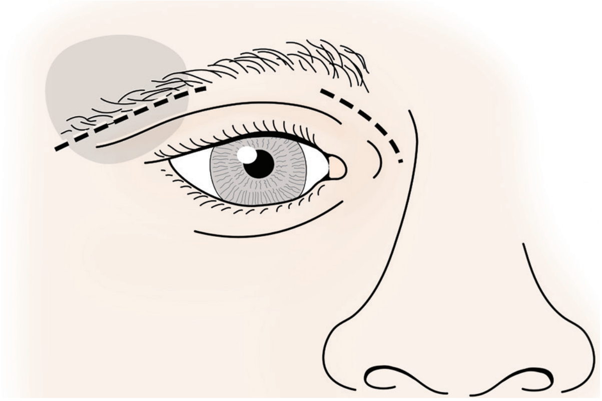

Figure 11.7 *An external angular dermoid is often a deeper lesion than originally appreciated and excision must be carefully planned to avoid scarring of the lateral eyebrow. The medial (Lynch–Howarth) incision is suitable for the drainage of orbital pus secondary to an ethmoid sinusitis.*

Tarsorrhaphy

Tarsorrhaphy is a simple temporary manoeuvre to save an eye because if an eyelid does not close over an eye during blinking and in sleep, drying of and trauma to the cornea follows, with impairment of sight. The underlying pathology may be a facial nerve paralysis, a severe proptosis secondary to hyperthyroidism or periorbital tissue damage from burns or other trauma. In these circumstances a lateral third tarsorrhaphy will usually suffice, whereas a complete tarsorrhaphy may be required to protect an injured eye during healing. Fine plastic tubes are sutured externally along the whole or the lateral thirds of the upper and lower lids. A loop of suture material is then passed through the two tubes, which, when tightened, draws the lids together with an even pressure.[6] This technique allows simple painless opening of the lids to examine the eye. A more permament lateral tarsorrhaphy can be performed by making an incision along the lid margin, between the eyelashes and the openings of the meibomian glands, to create a raw surface, before sewing the upper and lower lids together. However, other definitive solutions may be preferable. For example, a patient with a facial nerve palsy may be better served in the long term by the insertion of a gold weight in the upper lid, combined with a procedure to support the lower lid.

Ectropion and entropion

Ectropion may simply be the result of senile involution, but when it occurs secondary to infraorbital scarring the deformity can be corrected by release of the scar tissue followed by full-thickness skin grafting.

Entropion may also occur with senile involution, but in areas of the world where trachoma is endemic it is commonly secondary to conjunctival scarring from this infection. The inverted eyelashes traumatise the cornea. Any infection is first eradicated, after which the entropion can be corrected by excision of the scarred conjunctiva and replacement with a free full-thickness mucosal graft from the mouth. It may also be necessary to divide and evert a deformed inturned tarsal plate. An alternative simpler strategy is radical excision of the inturned eyelashes without attempts to correct the underlying deformity of the lid. Everting sutures, which pass through the skin, tarsal plate and tarsal conjunctiva, may be a simple procedure that produces temporary relief of the entropion.

Tumours of the eyelid

Tumours that involve less than one-quarter of the length of a lid can be excised as a full-thickness wedge, followed by reconstitution of the eyelid.

Surgery within the orbit and of the eyeball

This is an area where a general surgeon without specific training has little to offer. The drainage of intraorbital pus is described above. Some surgeons may wish to train so as to be able to offer cataract surgery in remote areas, but most other intraorbital and intraocular procedures will probably be impractical.

Ocular injury

Ocular injuries can seldom be managed successfully by a generalist. The internal structures may have been disrupted by blunt trauma or the orbit may have been penetrated. A ruptured or lacerated eye should be sutured promptly to prevent loss of contents and collapse, which will further disrupt the internal structures.[7] If iris tissue is prolapsing through a corneal laceration, this tissue should be excised. However, an eye injury, especially one where the uveal tract is involved (iris, ciliary body and choroid), may occasionally induce a sympathetic ophthalmia in the contralateral eye, with loss of sight in this eye as well. The risk of this rare but devastating complication is reduced by early removal of an injured eye. Therefore, if an eye is severely injured and sight already irretrievably lost, procrastination over its removal may be harmful.

Exposure of the posterior sclera is essential when a ruptured globe is suspected, as many ruptures start or extend posteriorly. A 360-degree conjunctival incision is made at the limbus (just outside the corneal–scleral junction) and all four quadrants of the sclera are exposed. A rectus muscle may have to be temporarily detached for access, but is later reattached with 6/0 absorbable sutures. A scleral wound is sutured with fine interrupted monofilament sutures and the conjunctiva reattached at the limbus with fine, absorbable sutures.

Enucleation

Enucleation of an eye is indicated for an intraocular malignancy and is also an alternative to evisceration for an eye destroyed by infection or trauma. The conjunctiva is incised at its junction with the cornea and the plane developed around the eyeball. Each intrinsic muscle is hooked forwards and detached from the globe. One stump should be cut long enough for an artery forceps to be attached for retraction. Finally, the optic nerve is divided, the eye removed and the conjunctiva closed.

Evisceration

Evisceration is a more common procedure in which only the contents of the globe are removed. It allows a better cosmetic result as there is some movement of the residual tissue. The cornea is excised and the contents curetted. All uveal tissue must be removed otherwise the patient is still at risk of sympathetic ophthalmia. In the absence of infection, four radial scleral incisions, towards the optic nerve and avoiding the extraocular muscles, create flaps that can be sewn together to form a central nubbin of tissue over which the conjunctiva can be closed.

SURGERY AROUND THE MOUTH

This surgery is predominantly the province of the maxillofacial, plastic and head and neck/ENT surgeons, although the general surgeon may be involved to a greater or lesser degree when these specialist services are unavailable.

Trauma

Lacerations of the lip can leave an ugly scar with a step at the vermilion border if not apposed accurately. Full-thickness lacerations require separate suturing of the layers. The mucosa is repaired first with absorbable sutures, followed by repair of the orbicularis oris muscle and finally the lip margin and the skin are closed. Small lacerations confined to the inside of the mouth seldom require sutures. An exception is a full-thickness laceration on the lateral border of the tongue. When a quarter or more of the tongue is divided, the muscle contraction holds the laceration widely open, and a couple of loose absorbable sutures are required for tissue apposition. Deep bites are necessary or the suture will cut through.

Infections and calculi

Infections within the mouth and oropharynx are discussed above. *Salivary calculi* are discussed in Chapter 10.

Malignancies

The lip

Tumours of the lip can be removed by a wedge incision. On the lower lip up to one-third of the length of the lip can be excised with a satisfactory cosmetic result. The incision must be carefully planned and the defect is closed as for a full-thickness lip laceration (Figure 11.8). On the upper lip, however, a wedge excision produces a noticeable asymmetry and, therefore, except for very minor wedge excisions, a flap reconstruction should be considered. Extensive premalignant leukoplakia of the lower lip can be excised by vermilion advancement. An incision is made just outside the whole length of the mucocutaneous junction and the mucosa is dissected off the underlying muscle as far as the gingivolabial sulcus. The leukoplakia is excised, after which the mucous membrane is advanced and reattached to the skin incision to form a new vermilion border.

The buccal mucosa

Tumours of the buccal mucosa can be simply excised if they are small and confined to the mucosa. They may, however, arise in an area of extensive premalignant field change in mucosa damaged by carcinogens. Extensive stripping of the abnormal mucosa may then be necessary, after which the defect is covered with a split-thickness skin graft. The graft should be secured to prevent displacement. A ‘quilting’

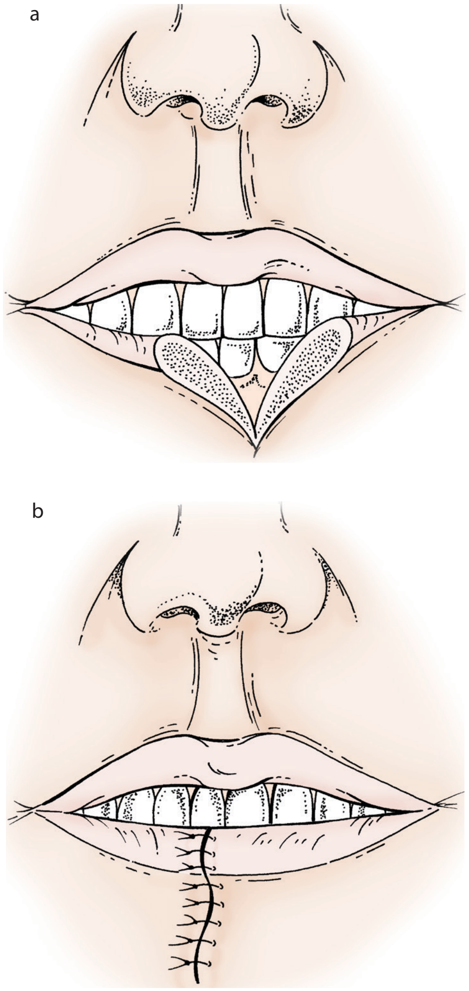

Figure 11.8 *A carefully planned V excision of a lip tumour can give an excellent cosmetic result. (a) The sides of the V are curved to increase the initial depth of the lip and compensate for later contracture of the scar. (b) Alignment of the vermilion edge is crucial for a good cosmetic result.*

technique, in which multiple sutures 1 cm apart are placed through the graft to tether it to the underlying muscle, is satisfactory. Advanced tumours of the buccal mucosa may require a radical full-thickness excision of the cheek. A myocutaneous pedicled flap may then be required for reconstruction (see below). If resection of such tumours involves the parotid duct, then relocation is mandatory if iatrogenic obstructive sialadenitis is to be prevented.

Other malignancies

Other intraoral malignancies can pose major challenges in resection and reconstruction. Small tumours on the tongue or elsewhere in the oral cavity can be excised locally with the removal of 1 cm of macroscopically normal tissue. Unfortunately, isolated generalists are more likely to see patients with advanced invasive malignancies. Surgeons who have no head and neck specialist referral possibilities usually have no access either to radiotherapy or chemotherapy. Curative surgery, or even palliative surgery to gain local control, will have to be very major.[8] General surgeons, even if they have the surgical skills to attempt these operations in unfamiliar surgical territory, are most unlikely while working in a small isolated hospital to have the anaesthetic or other facilities available to make such surgery a viable undertaking.

Congenital abnormalities

A *tight frenulum* tethering the tip of the tongue is a common minor abnormality. Frenulotomy, a simple release of the fibrous band, is all that is sometimes required, but care must be taken not to cut too deep and cause haemorrhage, which can threaten the airway. The submandibular duct orifices are also vulnerable to injury. When severe tongue tie exists, early release has been shown to reduce the incidence of mastitis in breastfeeding mothers. Social advantages include the ability to protrude the tongue, whether as an insult or to lick an ice-cream. Tongue tie is seldom associated with speech difficulties.

CLEFT LIP AND PALATE DEFORMITIES

Cleft lip and palate deformities are commonly linked, but either may occur in isolation. Early feeding difficulties, due to an inability to suck, are later overshadowed by speech problems from the cleft palate or the cosmetic distress from the cleft lip. Specialist repair undertaken in infancy can offer excellent functional and cosmetic results even with severe variants of the deformity. In areas remote from medical services, most severely affected infants fail to feed and do not survive infancy, but children with milder forms of the abnormality may present in late childhood in the hope that the deformity can be improved.

When no specialist referral is possible either to a specialist unit or a visiting short-term mission[9], a generalist can still improve the cosmetic appearance of a cleft lip. In milder cases the cleft is commonly unilateral, but with the inevitable associated distortion of the nose (Figure 11.9). The repair entails paring the edges of the cleft, lengthening the cleft side of the lip to bring the cupid's bow into a horizontal position, and identification and dissection of the abnormally placed fibres of the orbicularis muscle. These fibres, on either side of the cleft, will be found sweeping upwards and gaining an attachment to the alar base laterally and the base of the columella medially. These bundles must be detached, brought down to a more horizontal position and sutured across the lip to form a new orbicularis oris sphincter.

One of the many possible approaches is illustrated in Figure 11.9. The first step is to plan accurately and mark the skin incisions before starting the operation. Three areas of tissue will be excised. These include the two areas above the dotted lines in Figure 11.9a, where the two halves of the cleft upper lip extend up into the nostril. In addition, the small triangle **a-b-c** is excised. As the lip is pulled over, this triangular defect will allow lengthening of the new midline vermilion border, with localised narrowing of the lip to create a natural indentation, or cupid's bow. The additional full-thickness releasing incision, extending up from point **c**, is combined with the freeing of the abnormal attachment of the orbicularis muscle fibres to the columella, so that this portion of the lip can be drawn downwards. The extension of the incision under the nostril from point **e**, combined with the freeing of the orbicularis muscle fibres from the alar base, allows this other half of the lip to be drawn across and down.

As the tissue is drawn into its new position, for the initial approximation of **c** to **d**, the releasing incision above **c** opens up and point **e** will lie naturally within it. The underlying muscle fibres will also have been carried into a horizontal position and are correctly aligned for the deeper aspects of the repair (Figure 11.9b). Mucosa, muscle and skin are apposed with fine sutures and if mobilisation has been adequate, there should be no tension. There should also be a significant narrowing of the splayed nostril (Figure 11.9c).

An isolated generalist may occasionally wish to attempt repair of a cleft palate, but will require skilled anaesthesia to make this a viable procedure, especially in a young child.[10] Optimum results are obtained with extensive skilled mobilisation of tissue and additional repair of the floor of the nose. A simplified technique consists of the raising of mucoperiosteal flaps off the bony surface of the hard palate. The posterior palatine arteries are identified and preserved (Figure 11.10a). The soft palate muscles are then detached from their abnormal attachment to the posterior border of the hard palate and swung medially across the defect and sewn together (Figure 11.10b). The oral mucosal flaps are then also swung medially over the defect and sutured (Figure 11.10c).

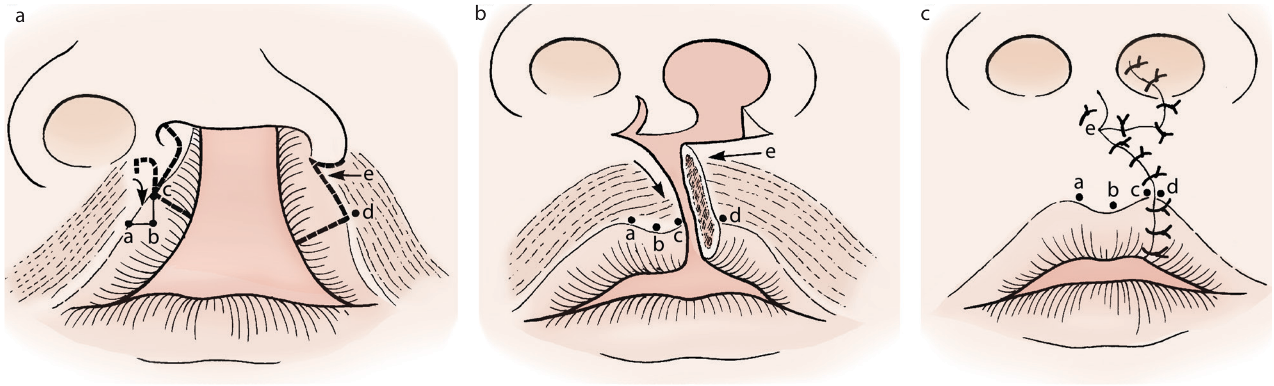

Figure 11.9 *Cleft lip repair. (a) The operation should be planned and the tissues marked before the incisions are made. (b) The incisions have allowed the muscle to be swung down into a horizontal position and the defect can now be closed. (c) A good repair should also correct the alar distortion.*

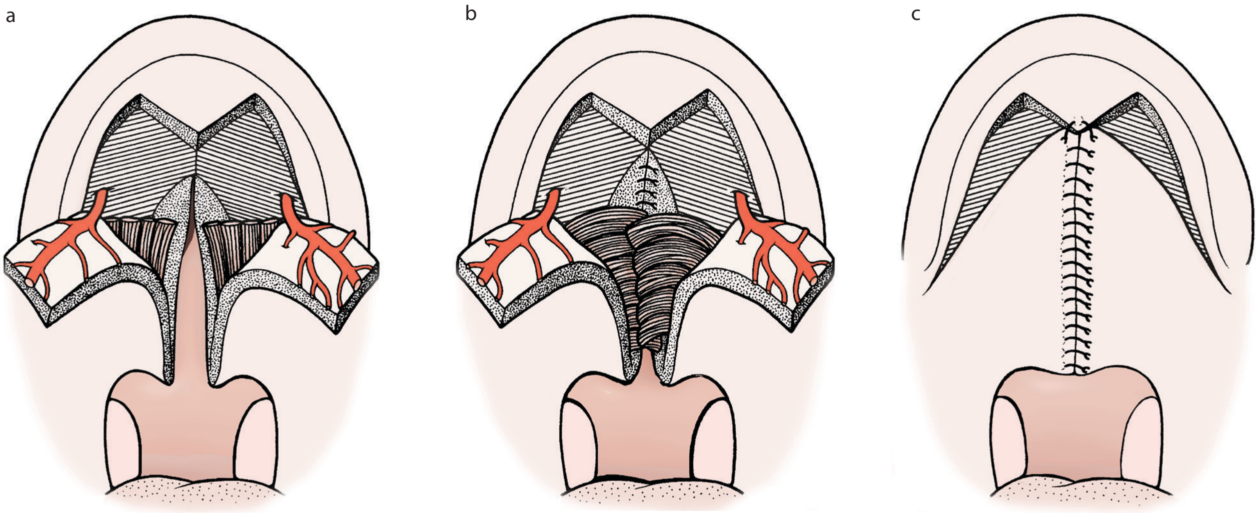

Figure 11.10 *Cleft palate repair. (a) The mucoperiosteal flaps have been raised with preservation of the posterior palatine arteries. The abnormal attachments of the soft palate muscles have been divided. (b) The muscles are then swung medially over the defect and sewn together. (c) The oral mucosal flaps are also apposed in the midline.*

Reconstruction around the mouth

MYOCUTANEOUS FLAPS

Myocutaneous flaps are invaluable for reconstruction following tissue loss from trauma, malignancy or necrotising infection. In the developed world they are exclusively within the practice of plastic or maxillofacial surgeons, and a wide range of donor flaps exist, especially if expertise in microvascular surgery is available to make free tissue transfer possible (see Chapter 2). Unfortunately, many of the patients requiring reconstructive surgery have been injured in military conflict in regions where the same conflict has disrupted medical services. Resources are limited and even a delayed evacuation for specialist surgery may be impossible. Two simpler flaps are described that may be of use to general surgeons who have no option but to attempt reconstruction themselves. As discussed above, they should not be undertaken as part of the primary procedure in trauma.

Pectoralis major flap

A pectoralis major flap can be brought up for soft tissue reconstruction. The original injury may have been from a bullet or a landmine explosion, but the wound has healed with major deformity from soft tissue loss. To plan the flap, a line is drawn from the acromion to the xiphisternum. A perpendicular line from the upper end of this line to the midpoint of the clavicle marks the course of the pectoral branch of the thoracoacromial artery, which supplies the flap. An incision is made around the required island of skin at the lower end of the flap (Figure 11.11) and this incision is deepened down to the pectoralis major muscle. In the medial portion of the ellipse, the incision is then deepened through the underlying pectoralis muscle to define the area of muscle that is required for the reconstruction. A linear skin incision is then made from the skin island along the axis of the flap. This affords the necessary access for the dissection of the flap pedicle. The plane under the lateral border of pectoralis major is then entered, and the dissection continues on the deep surface of pectoralis major to elevate a muscle pedicle by lifting it progressively off the underlying chest wall. Initially, the muscle pedicle is cut of similar width to the muscle underlying the skin island. The vascular pedicle, on which the vitality of the graft depends, can then be identified on the undersurface of the muscle as the dissection continues superolaterally. Once the vessels have been identified, the muscle pedicle can be narrowed to reduce its bulk. Finally, the humeral attachment of the muscle pedicle is divided to allow the pedicle to be tunnelled under the skin, in front of the clavicle, into the neck. It is then delivered into the defect where it is to be used, either in the neck or face.

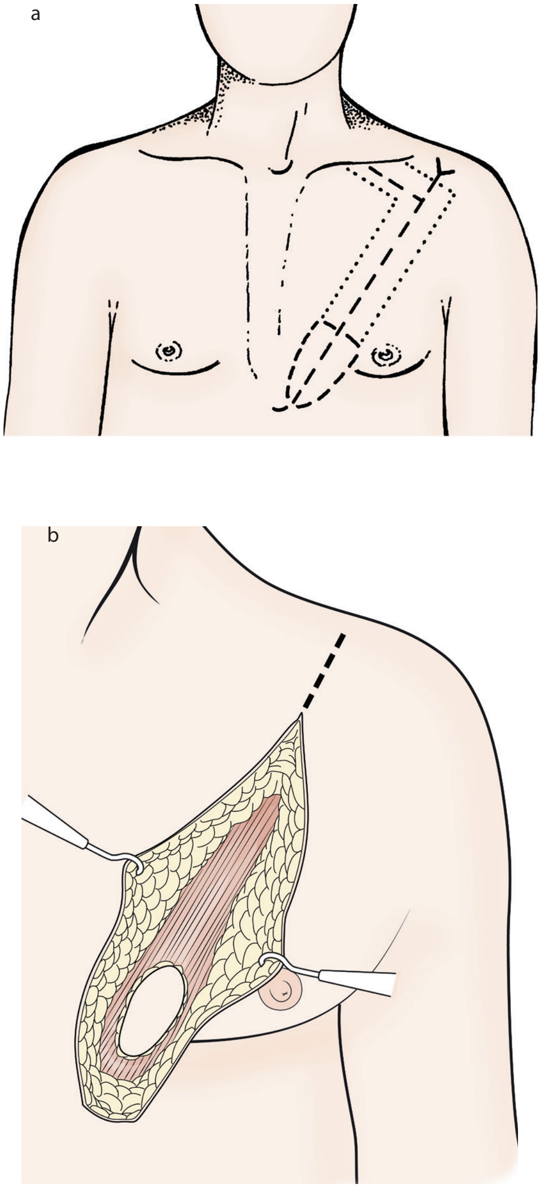

Figure 11.11 *A pectoralis major myocutaneous flap can bring an island of skin to the lower face for reconstruction. It has a more secure blood supply and reaches further than the alternative fasciocutaneous deltopectoral flap.*

Forehead flap

A lined forehead flap can be used to replace full-thickness tissue loss of the nose or cheek. This can be invaluable in reconstruction after cancrum oris or after a full-thickness excision for an invasive carcinoma of the buccal mucosa. The end of the forehead flap is lifted and a split-thickness skin graft is stitched to the undersurface. The flap is then resutured into place in order to give the split skin time to attach (Figure 11.12a). After 2 weeks the flap can be elevated and swung into position. The split-skin graft is sewn to the edges of the mucosal defect and the forehead skin to the defect in the facial skin (Figure 11.12b). The denuded area of forehead is covered with a split-skin graft, the bulk of which is only for temporary cover. After 3 weeks the pedicle of the flap is divided and the attachment of the donor tissue to the superolateral edge of the defect is completed. The remainder of the flap can then be returned to the forehead. The temporary split-skin graft is removed; it can be replaced by the return of the flap pedicle but is maintained over the small defect that remains.

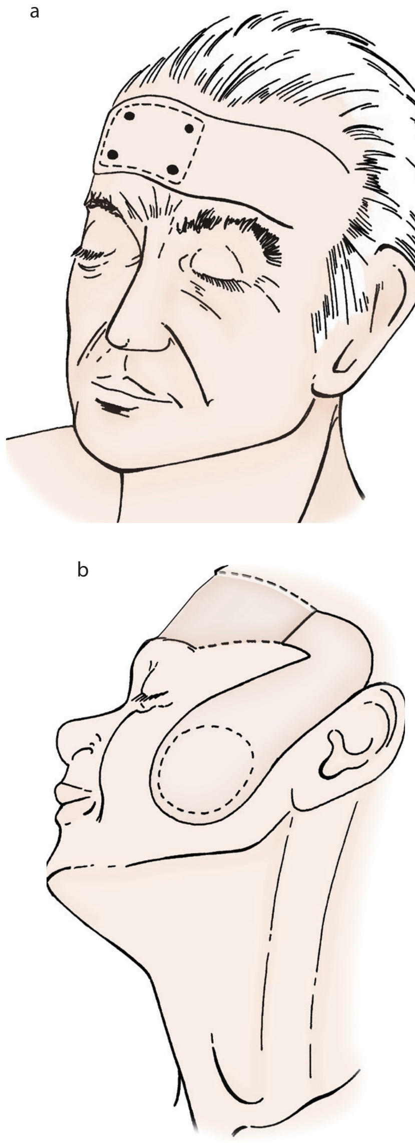

Figure 11.12 *(a) A forehead flap can be swung down for reconstruction of the nose or cheek. The forehead defect can be covered with a partial-thickness skin graft, which would not be suitable for the full-thickness tissue loss in the recipient area. (b) Lining of the undersurface of the flap with split skin, as described in the text, makes this flap suitable for the cheek, when buccal mucosa loss must also be replaced.*

SURGERY AROUND THE EAR

Trauma

Haematoma

Haematoma of the auricle should be drained on presentation. The skin is lifted away from the normally adherent cartilage by blood clot. Ischaemia from pressure occurs to the underlying cartilage and the clot becomes organised. If no action is taken, a 'cauliflower ear' develops. An incision along the antihelical fold must be made with strict asepsis in order to prevent perichondritis. Once all clot has been removed, a pressure dressing is applied, using saline-soaked cotton wool moulded to fill all the contours of the auricle. The ear must be examined daily because further accumulation of fluid will often occur for many days. If fluid continues to accumulate, then small silastic sheets (or small buttons as a satisfactory alternative) may be used to act as compression. These are placed on either side of the auricle and sutured together through the auricle.

Earring tears

Tears from earrings occur when an earring in a pierced ear is forcefully pulled through the tissue. In the acute presentation, the tissue is simply reapproximated. Late presentation is common when the patient discovers that healing has produced an unattractive, bilobed appearance. Reconstruction is simple and usually heals without complication.

Head injuries

Blood in the external meatus, in the absence of any obvious superficial injury, is very suspicious of a fracture of the petrous temporal bone, even if basal skull X-rays are not confirmatory. This is a compound fracture with the potential for intracranial infection, but local policies vary as to the use of prophylactic antibiotics in this situation (see also Chapter 9).

Cysts and other benign lesions

Multiple *small sebaceous cysts* around the ear, associated with the scarring of acne, can be very challenging to excise. Care must be taken to avoid full-thickness 'buttonholing' of the earlobe. A cyst related to an ear-piercing track is commonly an inclusion dermoid and can be excised. It is important to differentiate an inclusion dermoid from a keloid scar, the excision of which is unwise, as it is likely to result in a larger keloid.

Accessory auricles are most commonly small anterior skin tags with a core of cartilage. Excision is cosmetic and should include the core of cartilage, which extends deep to the skin.

Tumours of the auricle

There is virtually no mobility of the skin of the external ear on the underlying cartilage, and isolated skin closure after excision of a lesion is seldom possible. A full-thickness skin graft can be used after excision of a centrally placed (conchal) lesion if underlying tissue on which to place a graft has been retained. However, cartilage is unsuitable as a base and should be excised before placing the graft. Tumours at the edge of the external ear can be excised with the underlying cartilage in a full-thickness wedge excision (Figure 11.13). The V-shaped incision is easy to close, provided that a little more cartilage than skin is excised. Sutures are only required in the skin. Flap reconstruction may give a better cosmetic result when very large excisions are necessary.

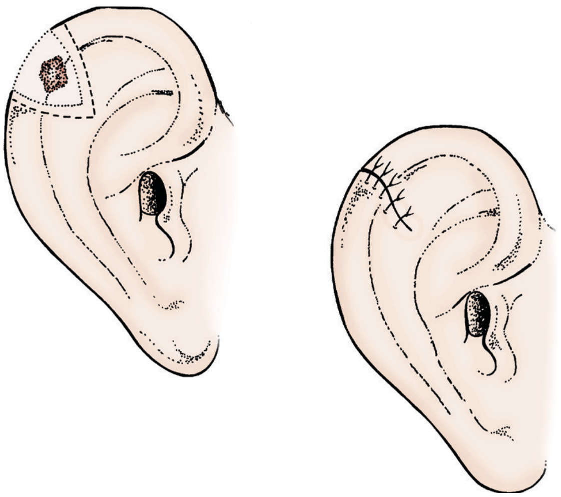

Figure 11.13 *Wedge excision of a tumour of the external ear. The broken line indicates the slightly wider excision of the cartilage.*

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12

SPECIAL CONSIDERATIONS IN ABDOMINAL AND GASTROINTESTINAL SURGERY

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Intra-abdominal surgery has the potential for major physiological, biochemical and septic complications that are seldom encountered in other areas. The main contributor to these derangements is the gastrointestinal tract, both its contents and its function. The details of these considerations are outwith a book on operative surgery, and further reading is essential for optimum preoperative and postoperative management.[1] However, an understanding of the issues involved is also essential during the surgery itself. Frequently, there is a choice of surgical solutions to a problem and the surgeon must decide before, or even during, an operation which is the most appropriate. Many factors are important in these decisions, but some general principles that may influence decisions are discussed in this chapter.

FLUID AND ELECTROLYTE DISTURBANCES

Fluid and electrolyte requirements should be considered in two main categories, namely maintenance requirements and replacement of abnormal losses. In Appendices I and III, the daily fluid and electrolyte maintenance requirements are given for adults and children. When there is intra-abdominal pathology the situation may be very different, as an imbalance develops in the fluid turnover throughout the gastrointestinal tract. Approximately 6 litres of fluid are secreted into the healthy, adult gastrointestinal tract and then reabsorbed each day (Table 12.1). In most abnormal situations, secretion continues, even if somewhat reduced, but reabsorption is greatly impaired. The fluid may be lost externally as vomit or nasogastric aspirate, as diarrhoea or as stoma or fistula effluent. Measurement of these losses in a hospital patient gives a guide to replacement requirements. However, patients with acute intra-abdominal pathology may present to hospital already in a state of advanced dehydration, and fluid and electrolyte deficits must be addressed prior to surgery. It must be remembered that fluid may also be lost from the circulating volume into the distended gut lumen or into the peritoneal cavity with no external losses apparent. The electrolyte content and acidity of intestinal fluids vary (Table 12.1) but in general, gastrointestinal fluid losses should be replaced with intravenous normal saline with added potassium, in addition to the basic maintenance requirements. During the period that an ileus is resolving, reabsorption of fluid from the bowel lumen back into the intravascular compartment occurs. If fluid replacement is not cut back at this stage, then fluid overload may occur.

Obstruction

The level of an obstruction, the history of vomiting and the degree of distension are clearly important when considering potential fluid and electrolyte disturbances. In a pyloric or jejunal obstruction, large volumes of fluid are still secreted into the lumen but are not reabsorbed. Fluid is lost as vomit

Table 12.1 Gastrointestinal secretions.

Secretion	Daily volume (ml)	Na^+ (mmol/l)	K^+ (mmol/l)
Saliva	1,000	10	25
Gastric	1,500	60	10
Bile	500	140	5
Pancreatic	500	140	5
Small bowel	3,000	140	5
Colonic	Minimal	60	30

The values given are only a guide and have also been approximated for simplicity.

or aspirate, and distension may be minimal. In contrast, in a distal ileal obstruction distension may be very marked before vomiting commences, and the fluid deficit may again be underappreciated. A distal large bowel obstruction is often initially incomplete, the absorption of fluid from the gut lumen continues and distension may be minimal until the passage of flatus is also prevented. Vomiting also usually occurs late.

Peritonitis and pancreatitis

The volume of circulating fluid that can be lost into the retroperitoneum, the peritoneal cavity and the oedematous gut wall is often underestimated in severe intra-abdominal inflammatory conditions and is often up to 10 litres or more.

Fistulae and stomas

Fistula effluent may lead to fluid and electrolyte depletion. A jejunal fistula or stoma necessitates intravenous replacement of the large volumes of fluid lost, but a colostomy or colonic fistula should cause minimal disturbance to fluid and electrolyte equilibrium.

VOLUME AND PRESSURE DISTURBANCES

In both mechanical obstruction and ileus, there is distension of the bowel and stasis of gastrointestinal contents. Stasis encourages bacterial overgrowth, with the formation of excess gas and resultant increasing distension. The distended gut is increasingly compromised and both fluid reabsorption and peristaltic function are further impaired. A vicious circle is established (Figure 12.1), especially as the greater the diameter of the bowel the greater the force of the peristaltic wave required to produce an effective propulsion. This is the situation encountered in a severe postoperative ileus and the explanation of the dramatic resolution that may occasionally occur following nasogastric tube deflation.

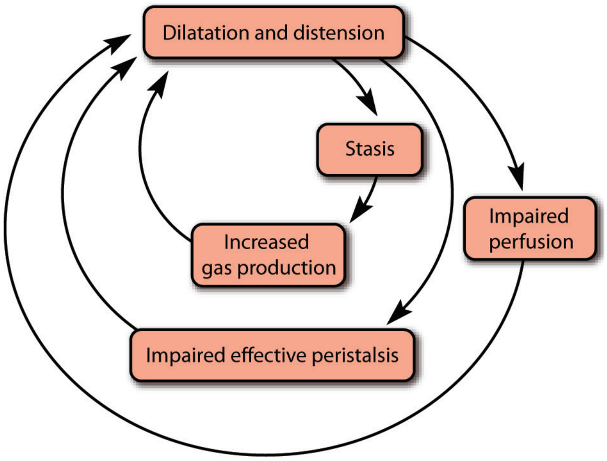

Figure 12.1 *The deteriorating pathophysiology of bowel obstruction.*

Gut distension inevitably leads to increases in intraluminal pressure and also to increases in intra-abdominal pressure and volume. Morbidity is increased.

Increased intraluminal pressure

Deterioration in gut perfusion occurs in gut distension. As the intraluminal pressure rises, it approximates the pressure in the vessels of the bowel wall, and effective perfusion ceases. Gross distension of the large bowel from a distal obstruction with a competent ileocaecal valve causes the caecum to distend more than any other segment of the colon. The caecum develops patchy gangrene and finally ruptures. Distension of the whole gut, as seen with a large bowel obstruction and an incompetent ileocaecal valve, is unlikely to cause such an isolated problem. However, the combination of increased intraluminal pressure and the general rise in intra-abdominal pressure impairs gut perfusion. Translocation of gut bacteria through the wall of a compromised bowel ensues, with systemic sepsis (see below) if treatment is delayed.

Increased intra-abdominal pressure

Oesophageal reflux may occur from a distended stomach, with resultant oesophagitis. Minor episodes of aspiration may present as inhalation pneumonia. A major vomit may result in the aspiration of a large volume of gastric contents and either sudden death or severe chemical pneumonitis with the development of an acute respiratory distress syndrome.

Abdominal compartment syndrome is a potential complication of abdominal distension with high intra-abdominal pressure.[2] The mechanism is similar to that of the compartment syndromes in the muscle compartments of the limbs (see Chapter 4). As the pressure rises within the abdomen, the perfusion of all intra-abdominal organs is reduced. Renal and hepatic perfusion are impaired and function deteriorates. Any anastomosis in the relatively ischaemic bowel is more vulnerable. Poor bowel perfusion also further hampers the resolution of ileus but additionally, and most importantly, the integrity of the 'gut to circulation interface' is jeopardised. Translocation of endotoxins and bacteria from the gut lumen into the portal circulation ensues, and is thought to be an important factor in multiorgan failure. Prognosis is poor once this situation is established and thus it is important not to create the problem by overzealous attempts to achieve primary abdominal closure. In severe forms there may be a grossly distended abdomen, a splinted diaphragm and distended superficial veins in the thigh from impaired venous return, but more minor forms may go unrecognised as one of the causes of a deteriorating clinical situation. However, the decision as to whether to return to theatre to release the pressure is seldom straightforward.

Increased intra-abdominal volume

Difficulties with abdominal closure following laparotomy are common when the intra-abdominal volume is increased. Sutures may cut through fascia, and the risk of a burst abdomen or an incisional hernia is increased. The surgeon is also at increased risk of catching a loop of bowel in a suture during closure. If tension cannot be reduced by decompression of bowel, simple primary closure of the abdomen may not be appropriate. Temporary containment of the abdominal viscera or a laparostomy may have to be considered (see Chapter 13).

Respiratory complications are increased by the mechanical raising and splinting of the diaphragm. In severe cases, blood gas exchange may be inadequate. Even when satisfactory arterial blood gas levels are maintained, the underventilation of the lower lobes predisposes to basal pneumonia.

Most of these complications may also result from an increase in intra-abdominal volume and pressure from factors other than mechanical obstruction or ileus. Severe visceral swelling is associated with trauma, pancreatitis or intra-abdominal sepsis. Ascites, blood or packs may be reducing the available intra-abdominal capacity. A similar situation ensues when the abdominal capacity is inadequate to accommodate normal intra-abdominal contents that are returned to it. These abdominal contents may have been lying free in the amniotic fluid before birth in a baby with a congenital defect of the abdominal wall, or accommodated for many years within a giant adult hernia.

CONTAMINATION FROM GASTROINTESTINAL CONTENTS

The contents of the gastrointestinal tract are highly damaging to all tissue except the specialised mucosa with which they are normally in contact. The gastrointestinal contents may be released as a consequence of a traumatic or surgical breach of the integrity of the gut wall, or the viability of the wall may be damaged by infection or ischaemia. The chemical and enzymatic constituents of gastrointestinal secretions may cause direct tissue damage, but bacterial contamination from intestinal contents is the most important consideration.

- *Chemical damage*. The acidity of gastric juice released into the peritoneum from a perforated duodenal ulcer causes the severe peritonism and reflex guarding associated with this condition. Sterile bile and small bowel contents are initially less toxic.
- *Enzymatic damage*. The enzymes within pancreatic secretions are released retroperitoneally in acute pancreatitis, and the profound local and systemic inflammatory response that follows occurs even in the absence of secondary infection.

Bacterial contamination

Gastric acid destroys most ingested bacteria and the contents of a healthy upper gastrointestinal system are relatively sterile. In achlorhydria or gastric stasis, however, bacterial growth continues in the stomach. The normal small bowel contents are also relatively sterile but, if there is stasis, bacterial overgrowth with faecal organisms occurs rapidly. Bile and pancreatic secretions are also sterile in health, but are often infected in situations where the secretions have escaped their normal confines. In contrast, the faecal material within a normal colon has a large bacterial component. Therefore, although perforation of the gastrointestinal tract at any level may release infection into the peritoneal cavity or retroperitoneal tissues, colonic perforation is the most serious in this respect.

Necrotic tissue does not maintain its physical integrity, and infarcted gut wall will inevitably perforate with release of the gastrointestinal contents. However, ischaemic but still viable gut also fails as an effective barrier and endotoxins, and finally bacteria, translocate into the circulation. In addition, the damaged ischaemic cells release cytokines and other tissue factors that initiate a cascade of inflammatory responses. The markers of this *systemic inflammatory response syndrome* (SIRS) include the rise in temperature, pulse and leukocyte count and the later development of a metabolic acidosis. It is these markers that the surgeon is monitoring during a trial of non-operative management. A deterioration in these indices may reflect, under different circumstances, ischaemic bowel, an anastomotic leak or intra-abdominal sepsis.

The bowel may be ischaemic from local occlusion of feeding vessels, as in a strangulation, or tissue perfusion may be reduced by increased intra-abdominal pressure. Perfusion is also reduced if a patient is hypotensive. Splanchnic vasoconstriction in shock reduces intestinal perfusion, which may be further jeopardised by the use of some pressor agents and inotropes in attempts to maintain blood pressure and perfusion to other vital organs. In all of these situations a bacteraemia or frank septicaemia may occur without any physical breach of the gastrointestinal tract.

Septicaemia with gut organisms after abdominal surgery is always suggestive of an anastomotic leak or non-viable gut. As discussed above, septicaemia may occur by translocation, but a second operation may still be necessary to exclude a surgically amenable disaster.

Surgery on the gastrointestinal tract is associated with a high incidence of septic complications, as some bacterial contamination of the surgical field is inevitable. Complications may, however, be reduced by mechanical and antibacterial measures.

MECHANICAL MEASURES

The prevention of spillage of gastrointestinal contents during surgery is key to reducing postoperative infective complications. Non-crushing bowel clamps, stapling devices and the protection of wound edges all have a role. Preoperative bowel preparation to empty the colon of faecal contents (see Appendix I) may have a role but has increasingly fallen into disuse. A change of contaminated gloves and instruments after the anastomosis is completed and careful peritoneal toilet if there is contamination are also recommended. Suction drainage of an area where a potentially infected haematoma may develop is a further mechanical measure to reduce septic complications.

ANTIBACTERIAL MEASURES

The most effective measure is prophylactic broad-spectrum systemic antibiotic cover just before and during the operation itself and for the first 24–48 hours afterwards (see Appendix II). This ensures that any intra-abdominal or wound collection of fluid or blood has an antibiotic content that will inhibit bacterial growth. Preoperative 'sterilisation' of the bowel with oral antibiotics was tried, but largely abandoned, as infection with resistant bacteria and yeasts was problematic. However, antibiotic decontamination of the digestive tract and replacing the normal gut flora with more harmless bacteria such as *Lactobacillus* spp. have both been shown to reduce septic complications and mortality in intensive care units.[3]

POSTOPERATIVE GASTROINTESTINAL FUNCTION

After intra-abdominal surgery there is an almost inevitable short period of gastrointestinal dysfunction, but it is now understood that many of the multifactorial causes of this ileus are avoidable. At operation the bowel should be handled gently and kept warm. Postoperative pain should be aggressively treated but the too liberal use of opiates should also be avoided.

Enhanced recovery

Combining various strategies known to improve postoperative recovery into an enhanced recovery programme can result in faster recovery from gastrointestinal surgery and a shorter hospital stay.[4] Programmes vary but in general they focus on early mobilisation and the minimisation of the period of perioperative starvation. Avoiding bowel preparation, achieving good analgesia without overuse of opiates and preventing perioperative fluid overload helps to reduce postoperative ileus and allows patients to start oral intake immediately on waking from anaesthesia. It is, however, important to identify patients in whom an ileus is still developing, as continuing to encourage oral intake merely increases gut distension and will delay resolution.

INTESTINAL FAILURE

Failure of the damaged gastrointestinal system to regulate fluid and electrolyte turnover is immediately apparent. The impaired nutritional function is unfortunately often ignored, despite the recognition, as early as the 1930s, of a higher mortality in malnourished surgical patients.[5] A previously healthy, well-nourished patient who makes an uncomplicated recovery from intra-abdominal surgery probably comes to little harm from a week of starvation. Many patients with intra-abdominal pathology, however, have had either no nutritional intake for several days before their emergency admission or have a long history of poor intake and weight loss over several months. If a good nutritional intake is then not established by the second postoperative week, a deteriorating clinical picture relating to starvation occurs. This situation should be avoided by commencing *enteral* or *intravenous feeding* before deterioration is evident (see Appendix III), and it is sometimes indicated from the time of surgery.

ENTERAL FEEDING

Enteral feeding is preferable to intravenous feeding provided the gut is functioning, and should always be considered; however, it is unfortunately often not feasible or is contraindicated. Enteral feeding has the advantage that the portal circulation is not bypassed and in addition, it preserves the luminal delivery of nutrients to the gut mucosa. This is now known to be important in the prevention of enterocyte and colonocyte dysfunction. The septic complications of intravenous feeding are also avoided. If there is upper gastrointestinal dysfunction, it may still be possible to feed enterally if the feed is delivered more distally. For example, if a prolonged gastric ileus is anticipated a *long double-bore nasogastric tube* can be passed during the operation. The surgeon guides the long end through the duodenum into the first loop of jejunum. The shorter end remains in the stomach for gastric aspiration (Figure 12.2). Alternatively, a *feeding enterostomy* may be introduced directly into the jejunum at the time of surgery. This form of feeding jejunostomy has the advantage of sparing the patient a nasogastric tube solely for the purpose of feeding, but the jejunal puncture and fixation of the jejunum to the abdominal wall have the potential for complications. A needle is introduced obliquely through the jejunal wall through which a catheter is threaded (Figure 12.3). The needle is withdrawn and a purse-string suture inserted. A similar needle is then used to guide the catheter through the abdominal wall. The jejunum is then fixed to the abdominal wall to prevent kinking.

Enteral feeding should be introduced slowly and increased as tolerated. Long-term gastrostomy feeding may be indicated in patients with oesophageal pathology and also in patients with dysphagia secondary to neurological disorders.

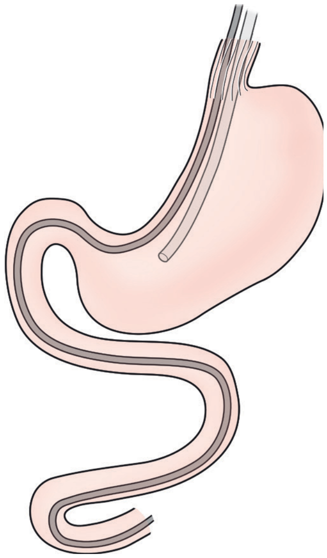

Figure 12.2 *A double-lumen nasogastric tube is placed so that the short tube is in the stomach for gastric aspiration. The longer tube should lie through the duodenum, well into the first loop of jejunum. More proximal positioning will result in reflux of jejunal feed into the stomach.*

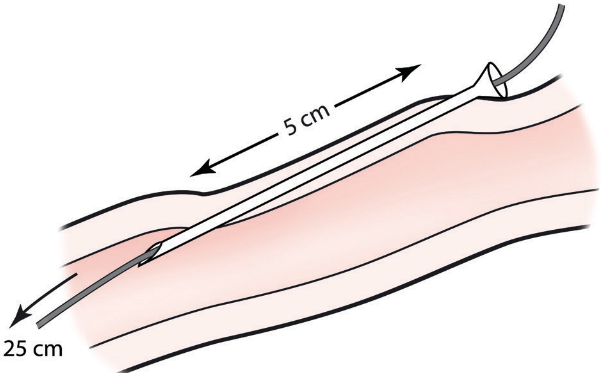

Figure 12.3 *A 7-cm long, 16-gauge needle is introduced through the jejunal wall so that there is a 5 cm intramural track. A catheter is threaded through the needle and then distally within the lumen for a further 25 cm.*

The *feeding gastrostomy tube* can be introduced by the percutaneous endoscopic approach (Figure 12.4), and can be established in the endoscopy suite under sedation and local anaesthesia. Techniques vary with different devices, but one method is illustrated in Figure 12.4. An open gastrostomy is described in Chapter 14.

INTRAVENOUS (PARENTERAL) FEEDING

This is covered in more detail in Appendix III. It is best undertaken through a central venous catheter as hypertonic solutions cause thromophlebitis in peripheral veins. The placement of subclavian, internal jugular and peripherally inserted central catheters (PICC lines) is described in Appendix 1. The subclavian line is more comfortable than an internal jugular for the conscious patient. Long-term successful intravenous feeding depends on the absence of septic complications. Absolute sterility in the insertion of lines and in their maintenance is essential. A subcutaneous tunnel reduces bacterial contamination if the line is to be used in the long term (Figure 12.5).

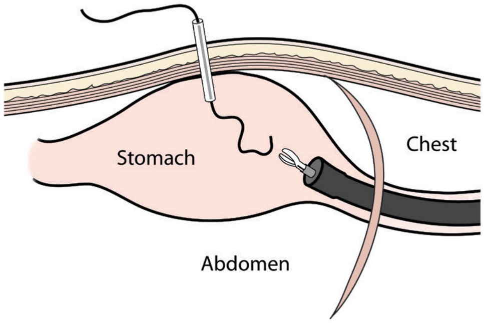

Figure 12.4 *Percutaneous endoscopic gastrostomy (PEG). The gastroscope is used to distend the stomach and elevate it against the anterior abdominal wall. A cannula is introduced into the stomach through a small incision made under local anaesthesia. A thread is then passed through the cannula, gripped through the gastroscope, and delivered out through the mouth where it is attached to the gastrostomy tube, which is then gently pulled down into place.*

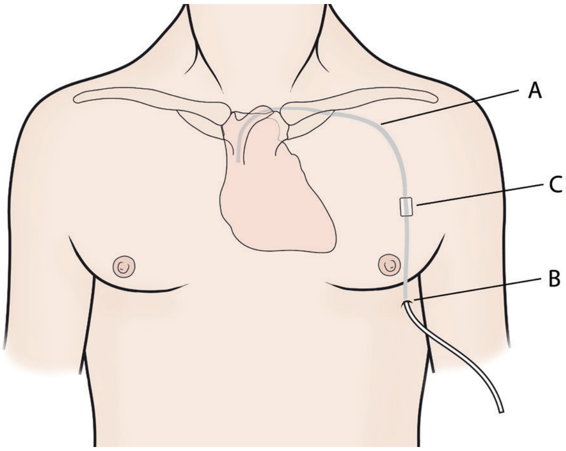

Figure 12.5 *A long-term line with a subcutaneous tunnel has less infective complications. A is the point from which the line is inserted into the subclavian vein (see Appendix I). B is the exit point of the line through the skin after the additional subcutaneous tunnel has been created. At C there is a Dacron cuff on a portion of the line lying in the subcutaneous tunnel. Reaction around this firmly tethers the line in place. When the line is removed, a small incision must be made at this point to release the cuff.*

Temporary intestinal failure

This is common when postoperative recovery is complicated by sepsis and ileus. Enteral feeding is seldom possible, but after a variable period of intravenous feeding gut function recovers. Ileus often resolves surprisingly quickly after the commencement of intravenous feeding, and the parenteral nutrition may even have initiated the recovery of gut function. It must be remembered that a patient suffering the ill effects of starvation will also have a bowel that is adversely affected by lack of nutrients.

The importance of specific nutrients for intestinal mucosal function has been appreciated only relatively recently. Short-chain fatty acids are important nutrients for the colonic mucosa. The integrity of gut mucosa has also been shown to be dependent on glutamine, an amino acid that becomes conditionally essential in the critically ill. Reversible loss of function occurs in bowel deprived of luminal nutrients. This may affect the whole gut after a prolonged period of exclusively intravenous nutrition, or affect a segment of bowel from which the intestinal contents have been temporarily diverted.

Prolonged severe postoperative intestinal failure

This usually occurs in association with anastomotic breakdown, fistulae and intra-abdominal collections of intestinal contents and pus. These patients pose major management problems to the surgeon.[6,7] Initial treatment is resuscitation with correction of fluid and electrolyte imbalance, followed by restitution of body reserves with intravenous feeding. Any intra-abdominal collections of pus or intestinal fluid must be localised and drained effectively. This can often now be undertaken by percutaneous image-guided techniques, in which a collection is either aspirated or a drain introduced into it, secured and left *in situ*. However, an open operation may still sometimes be needed. It is not always possible to close the abdomen at the end of the operation due to high intra-abdominal pressure and some form of temporary abdominal containment may have to be considered (see Chapter 13). Any fistula effluent must be collected in order to prevent damage to the abdominal skin, and this can usually be achieved with skilled application of a stoma bag. If this is not possible, an alternative is a drain on low continuous suction. A simple home-made prototype, favoured by Eric Farquharson, is shown in Figure 12.6. Definitive surgery to repair a fistula should be delayed until the patient's general condition has improved and the peritoneal cavity has reformed as inflammatory exudate and adhesions are absorbed. This may take 6 months or longer. A clinical sign of this is a small bowel fistula starting to form a spout similar to an ileostomy.

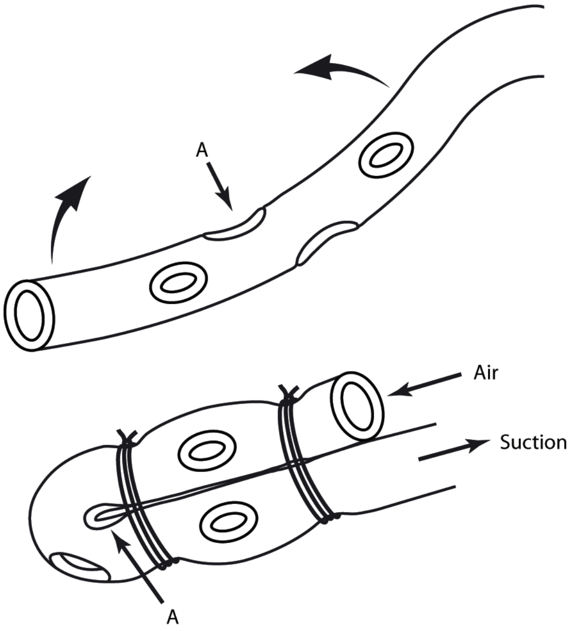

Figure 12.6 *A simple surface drain, constructed from a length of tubing, for the collection of fistula effluent from a deep granulating wound. Hole A allows the tube to be folded without buckling. The air sucked in from the open end prevents blockage of the holes by tissue drawn in by the suction.*

Long-term intestinal failure

A small proportion of patients require long-term nutritional support. The commonest cause of long-term intestinal failure is a short small bowel following major resection.[8] The surgeon may have had no other option when faced at emergency laparotomy with extensive small bowel infarction. This is discussed further in Chapter 23, but it is most frequently the result of a major vascular occlusion in the superior mesenteric vessels by an embolus or thrombus. A small bowel volvulus may also result in extensive infarction and subsequent resection of a large proportion of the small bowel. The other large group of surgical patients with intestinal failure are those who have severe Crohn's disease and have had multiple resections of severely diseased segments. The surgical management of Crohn's disease is discussed in Chapter 23, but in general, resections should always be planned so as to remove the minimum of normal bowel. However, attempts to avoid further resections in the presence of strictures may be nutritionally counterproductive. A partially obstructed small bowel proximal to a stricture becomes dilated, with resultant stasis and bacterial overgrowth. This causes mucosal damage, which impairs the absorptive capacity of an otherwise normal segment of small bowel.

When a surgeon is planning a major small bowel resection, it is important that the length of small bowel that will be retained is measured accurately. This is the important measurement, not the length that is to be excised, as the normal small bowel length may vary between 300 and 850 cm. Preservation of the colon is now known to improve nutrition as well as reduce fluid losses after major small bowel resection. If less than 200 cm of small bowel can be saved, some nutritional problems should be anticipated, but the common early difficulty is fluid loss. If less than 100 cm can be saved, the patient will need intensive nutritional support, with intravenous feeding during the early months. However, as there is some adaptation of the remaining bowel it may be possible later to wean the patient onto a normal oral intake with supplements. If less than 50 cm can be preserved, the patient will almost certainly need long-term intravenous feeding. The minimum lengths for adequate nutrition are, however, unpredictable and the maximum length of small bowel should always be preserved. If prolonged intravenous feeding is obviously impractical, as in the very elderly patient with major co-morbidity, a resection that leaves only a few centimetres of small bowel merely condemns the patient to a slower and more distressing death than deciding the situation is inoperable, closing the abdomen and giving adequate pain relief.

Small bowel transplants have been successful in selected patients with irreversible intestinal failure, and there has been particular enthusiasm in paediatric practice. There has not, however, been the same success as in other transplantation techniques and in general, small bowel transplants have no overall avantage over long-term home parenteral nutrition.[9]

COOPERATION BETWEEN SPECIALISTS IN ABDOMINAL PROCEDURES

Increasingly, many intra-abdominal problems that could previously only be managed by open surgery are now amenable to intervention by endoscopic or radiological techniques. The general surgeon must thus cooperate with other interventionalists, as discussed in Chapter 1 and in the ensuing chapters.

Within the abdomen, pathology in one system may result in complications in another. Diverticulitis or colonic cancer may cause a colovesical fistula. An infected aortic graft may present with an aortoduodenal fistula and gastrointestinal haemorrhage. Similarly, surgery on one system may cause complications in another. Surgery on the uterus or bowel may damage a ureter, and surgery on the aorta may render the colon ischaemic. Radiotherapy to one organ may damage another. Cooperation between surgical specialists is required both for these problems and for the extensive radical surgery sometimes indicated for advanced malignancy.

In reconstructive urological surgery, small bowel is required as a urothelial substitute, and the general surgeon may be involved in these operation or in the complications of such procedures. Small bowel is of great value within the abdomen and pelvis for reconstruction. Its excellent blood supply allows a segment to be isolated on its vascular pedicle, and the techniques are described in Chapter 22. The stomach or colon may be mobilised into the chest, or even up into the neck, to replace the oesophagus, and the general surgeon may be working with the thoracic or ENT surgeons.

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13

SURGICAL ACCESS TO THE ABDOMEN AND SURGERY OF THE ABDOMINAL WALL

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Access through the abdominal wall for open surgery must be made through an incision of sufficient length to allow the surgeon a good view of the operating field and to permit the entry of hands and instruments. An exception is an operation on a mobile structure that can be delivered through a small wound and the surgery performed outside the abdomen (e.g. appendicectomy). In laparoscopic surgery, the surgeon's hands remain outside the abdomen, while a gas-filled space is created into which the camera and instruments are inserted via trocars passed through the abdominal wall. Good views and operating conditions can be obtained for deep-set structures that would require large incisions for safe conventional surgery. Laparoscopic dissection must often be combined with a small incision at the end of the operation to deliver an intact specimen. For example, whereas an appendix or a gallbladder can be delivered through the camera port site, a right hemicolectomy specimen with a malignant caecal tumour cannot. (There is the added advantage in this scenario that the bowel ends are exteriorised for the anastomosis.) A compromise between laparoscopic and open techniques may also be beneficial. For example, a laparoscopic mobilisation of the splenic flexure allows the surgeon to perform an open left hemicolectomy through a much smaller incision. Laparoscopic surgery has advanced greatly in the last 20 years, and with refinement of both skills and equipment there is a choice of open or laparoscopic surgery for almost all intra-abdominal procedures.

GENERAL CONSIDERATIONS

Patient position

For most abdominal procedures the patient is supine. The general considerations are similar for all surgery and are discussed in Appendix II. It may be helpful in both open surgery and, more frequently, in laparoscopic surgery to roll the patient to one side or the other or to tilt the table steeply head-up or head-down for part of the operation. The patient must therefore be safely secured to the operating table. If pelvic dissection is anticipated, the legs should be elevated and suitably supported, as shown in Figure 13.1. Simple straps are suitable for a short operation, but the pressure points are inadequately protected and the hips are too acutely flexed for this position to be suitable for a more lengthy procedure. A 'legs-up' position allows access to the perineum for surgery, and there is room for an assistant to stand between the legs. For loin and thoracoabdominal incisions the patient may be in a full or partially lateral position. Lateral flexion of the patient will then increase the access between the ribs and between the costal margin and the iliac crest. This can be achieved by angulation of the upper and lower portions of the operating table or simply with placement of a sandbag (Figure 13.2).

Anaesthesia and relaxant

An intra-abdominal operation requires relaxation of the abdominal musculature in addition to anaesthesia. When a muscle relaxant is used in combination with a general anaesthetic, the patient must be ventilated. Spinal or epidural anaesthesia can provide good operative conditions for a lower abdominal laparotomy; the patient is conscious and able to breathe spontaneously, but the abdominal muscles are relaxed. This approach is less suitable for an upper abdominal laparotomy. Epidurals are also frequently used as an adjunct to a general anaesthetic, and are then continued for postoperative pain relief. Local infiltrative anaesthesia does not provide muscle relaxation and often gives poor anaesthesia of the parietal peritoneum. However, this can be

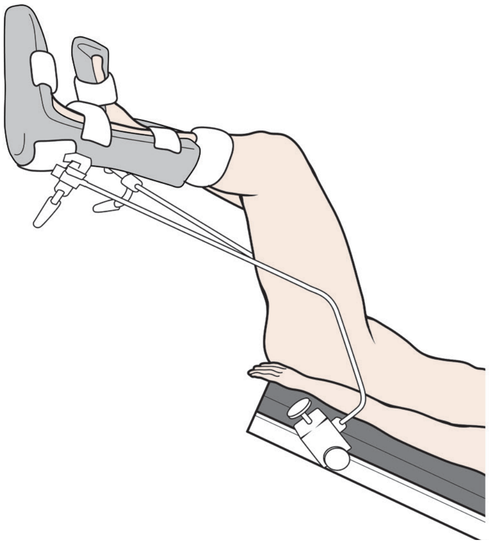

Figure 13.1 *The Lloyd Davis position, which is suitable for prolonged surgery. The perineum is accessible and an assistant can stand between the patient's legs. The Trendelenberg head-down tilt improves pelvic access as mobile abdominal contents fall out of the pelvis.*

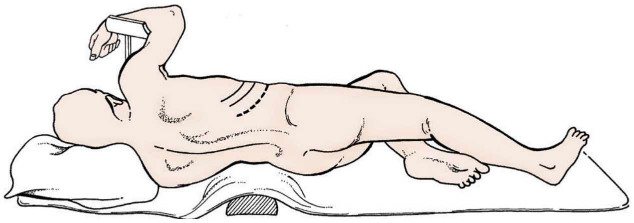

Figure 13.2 *Patients placed in a lateral position require support for the upper arm. They are more stable if one leg is flexed and one bent, but will still require restraints to prevent rolling. Lateral flexion induced by angulation between the two portions of the table increases loin access. If the operating table does not 'break', a similar position can be simply achieved with a sandbag.*

overcome by combining local infiltration with blockade of intercostal nerves as they emerge from under the costal margin. Although such local anaesthetic techniques may occasionally be useful, it must be remembered that the success of major intra-abdominal surgery, especially in the ill or elderly patient, is heavily dependent on the intensive intraoperative management of the patient by the anaesthetist.

Urinary catheterisation

A distended bladder is at risk of injury from a suprapubic laparoscopic port or a lower abdominal incision. Surgical access to the pelvis is also hampered by a bladder that is filling during the operation. In addition, for most major intra-abdominal surgery the anaesthetist will wish the patient to be catheterised so that intraoperative urine output can be measured. Urinary catheter drainage, if established, is often continued postoperatively, as it is easier for the patient during the first few days after major surgery. In addition, any elderly male patient who has had pelvic surgery, and any patient who is receiving epidural postoperative pain relief, will almost certainly develop urinary retention if not catheterised.

Gastric aspiration

Intraoperative gastric distension may limit surgical access in the upper abdomen, and a nasogastric tube, inserted by the anaesthetist before surgery is commenced, can be helpful. If a prolonged ileus or a delay in gastric emptying is predicted, the tube is left *in situ* for continued aspiration during the postoperative period.

ANATOMY OF THE ABDOMINAL WALL

Muscles

The muscles of the anterior abdominal wall are the external oblique, the internal oblique, the transversus abdominis and the rectus abdominis. (The pyramidales muscles are frequently absent and are of no surgical importance.) In general, the first three of these muscles have attachments to the lower ribs and the iliac crest. The internal oblique and the transversus abdominis also arise from the lumbar fascia. As they traverse the front of the abdomen, all three become aponeurotic and are inserted mainly into the *linea alba,* a band of fibrous tissue extending in the midline from the xiphoid process to the pubis. Before they reach the linea alba they combine to form a sheath for the rectus muscle. Above the umbilicus the linea alba is 1–2 cm wide, but in its lower part it is much narrower.

- *External oblique* runs mainly downwards, forwards and medially, but its upper fibres are nearly horizontal. Its lower fibres, inserting into the iliac crest, are nearly vertical. Its lower free border forms the *inguinal ligament*, which stretches from the anterior superior iliac spine to the pubic tubercle.
- *Internal oblique* runs mainly in a slightly upward and medial direction, but its lowest fibres, which descend to the pubis, are almost vertical.
- *Transversus abdominis* is the deepest muscle and it runs mainly horizontally, although its lowest fibres run downwards along with those of internal oblique as the conjoint tendon. Its deep surface is lined by transversalis fascia; between this and the peritoneum there is a layer of extraperitoneal fat of variable thickness.
- *Rectus abdominis* lies alongside the linea alba, stretching from the front of the pubis inferiorly to the xiphoid process and beyond to the 5th, 6th and 7th costal cartilages. Its substance is traversed by three horizontal *tendinous intersections,* one opposite the umbilicus, another near the xiphoid and a third midway between these.

RECTUS SHEATH

This is formed by the aponeuroses of external oblique, internal oblique and the transversus abdominis, the last two of which are arranged in a somewhat complicated manner (Figure 13.3).

The *anterior sheath* is complete from rib margin to pubis. In its upper three-quarters it is formed by external oblique and by the anterior lamina of internal oblique. In the lower quarter it is formed by all three aponeuroses. It is adherent to the tendinous intersections of the rectus muscle.

The *posterior sheath* is complete only as far down as a point midway between umbilicus and pubis, where it ends as a free border, the *arcuate line.* Below this level the sheath is deficient, the rectus being separated from the peritoneum by transversalis fascia alone. The posterior sheath is formed by the posterior lamina of internal oblique fused with transversus. Some fleshy fibres of transversus appear in the upper part of the posterior sheath. The tendinous intersections do not extend to the posterior surface of the rectus abdominis.

Vessels

The *inferior epigastric vessels* are of considerable surgical significance. The inferior epigastric artery, arising from the external iliac, passes medial to the deep inguinal ring as it runs upwards and medially on the deep aspect of the abdominal wall musculature and enters the rectus sheath at the arcuate line. The companion vein joins the external iliac vein. The smaller *superior epigastric artery* is a terminal branch of the internal thoracic artery and enters the sheath from under the costal margin. The two vessels have anastomotic connections within the belly of the muscle. It is this vascular arrangement that enables the surgeon to use the rectus muscle as a reconstructive flap, which can be swung cranially or caudally.

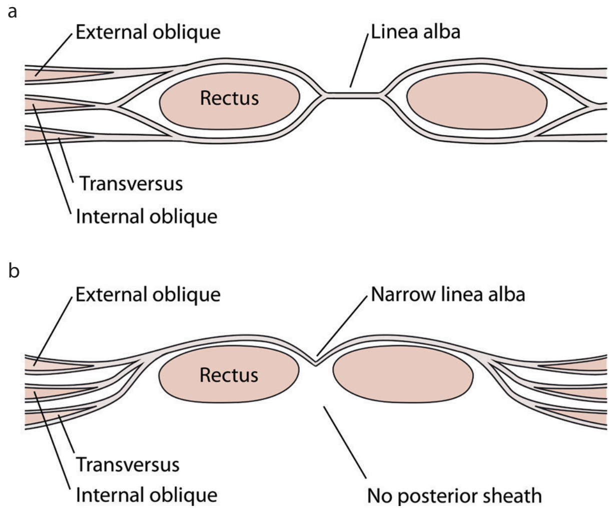

Figure 13.3 *The rectus sheath is formed from the aponeuroses of external oblique, internal oblique and transversus. (a) A transverse section of the sheath above the arcuate line; (b) a transverse section of the sheath below the arcuate line.*

Nerves

The nerves of the abdominal wall are the *lower five intercostals,* the *subcostal,* the *iliohypogastric* and the *ilioinguinal.* They run an oblique course in the abdominal wall, lying mainly between transversus and internal oblique. All except for the last two enter the rectus sheath and pierce the rectus to end as cutaneous branches.

INCISIONS FOR ABDOMINAL SURGERY

Common incisions are shown in Figure 13.4. The technique for opening the peritoneum is similar in all incisions and is therefore considered first.

Opening the peritoneum

Utmost care must be taken to ensure that no underlying viscus is injured during incision of the peritoneum. Except at the umbilical cicatrix and at surgical scars, the peritoneum is separated from the abdominal wall by a variable layer of extraperitoneal fat. When the peritoneum has been exposed, a small bite is taken with artery forceps and lifted forwards. The fold that is lifted up may be pinched between finger and thumb so that its thickness can be estimated. A second artery forceps is then applied alongside the first and the fold is carefully incised (Figure 13.5). If an opening is not immediately apparent, the forceps should be taken off and reapplied. As soon as the peritoneal cavity is opened, air enters and a space is created between the parietal peritoneum and the intraperitoneal structures. When the initial opening has been made, it

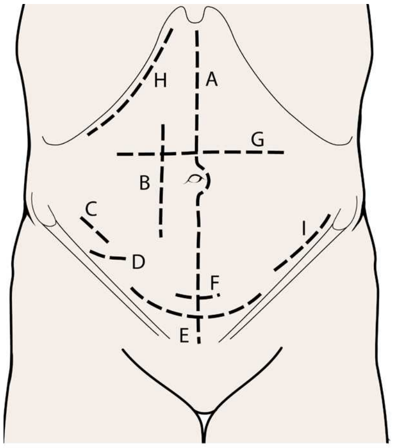

Figure 13.4 *A selection of common abdominal incisions. A = midline; B = paramedian; C = gridiron; D = Lanz; E = Pfannenstiel; F = suprapubic; G = transverse upper abdominal; H = subcostal 'Kocher'; I = oblique iliac muscle-cutting.*

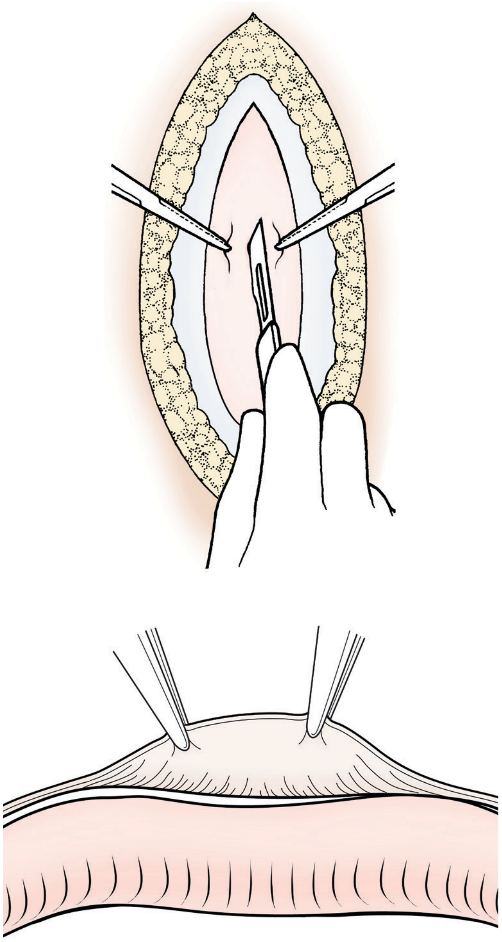

Figure 13.5 *The initial incision through the parietal peritoneum is inherently dangerous, as the peritoneal cavity is only a potential space until air can enter. The creation of a peritoneal fold between two forceps is a time-honoured manoeuvre to exclude bowel from this incision.*

is enlarged, usually by cutting with scissors or diathermy under direct vision. If the undersurface of the peritoneum is not visible, a finger should be inserted to check that no bowel is adherent to the peritoneum in the line of the incision. Particular care must be taken in opening an old incision, as the abdominal wall musculature and peritoneum are adherent and often fused into a single layer of fibrous scar to which loops of small bowel may be adherent. Even with great care, inadvertent enterotomy may occur and greatly increase morbidity.[1]

Midline incisions

Midline incisions provide good access to the whole abdomen. The linea alba may be divided from xiphisternum to symphysis pubis, although commonly a shorter incision is made and only extended if necessary. A large xiphisternum can be excised if it is restricting access. Troublesome bleeding may then occur from the terminal branches of the internal thoracic artery and this will require diathermy coagulation. The main disadvantage of a midline incision is that it crosses the natural crease lines of the skin and a hypertrophic scar is common, especially in young children. In addition to the cosmetic issues, the thickening and shortening of the scar at the waist crease may be irritated by clothes. The umbilicus presents an additional cosmetic challenge. A straight incision through the umbilicus is favoured by some surgeons, but most prefer to curve the incision around it, taking care to cut the skin perpendicular on the curve. Forceps placed on the umbilical skin, retracting it to one side and holding the skin taut while the skin incision is made, may be helpful. An alternative is to make the whole skin incision paramedian, followed by a midline incision through the linea alba.

The incision is deepened through the subcutaneous fat, and any bleeding vessels controlled, until the linea alba is exposed throughout the length of the incision. At the umbilical cicatrix the peritoneum is in close apposition to the linea alba, and this is often the easiest and safest place to gain access to the peritoneal cavity. Two forceps are applied to the linea alba, one either side of the midline, and it is lifted upwards while the fascia is carefully incised. If this incision does not enter the peritoneal cavity, the peritoneum is incised separately. The linea alba above and below the umbilicus is separated from the peritoneum by a significant layer of extraperitoneal fat and may be divided without immediate entry through the parietal peritoneum, which is then incised as a separate layer.

As the incision is extended it is possible, if exactly in the midline, to encounter no muscle fibres. Below the arcuate line, however, the linea alba is narrow and there is no posterior sheath. In addition, pyramidalis may be obvious. In this area visible muscle fibres do not indicate that the incision has strayed from the midline. The rectus muscles may be separated right down to the symphysis pubis, but care must be taken in extending the peritoneal division down to this level or an inadvertent incision may be made into the bladder. The peritoneal incision must therefore be deviated laterally if further low division is required for access. In the upper abdomen there is a significant pad of extraperitoneal fat, which extends a few centimetres either side of the midline. Some surgeons therefore prefer to divide the peritoneum lateral to this. The fold of the falciform ligament extending from the liver to the anterior abdominal wall may cause some confusion, and it may need to be divided for access. Vessels running within the ligament can cause troublesome bleeding if not secured.

Closure of a midline incision is perfectly adequate in a single layer (mass closure), with a continuous suture. The peritoneum may be included in the closure, but this is not essential as it will appose naturally when the fascia is closed. The suture material must retain tensile strength until the healing fascial scar has developed its own. Thus, either a nonabsorbable material should be used or an absorbable material that loses its tensile strength slowly. A strong (gauge 1 or 0) monofilament nylon or polydioxanone (PDS) suture is therefore suitable. Closure is started at one end and a knot formed. If the first stitch is inserted from under the fascia, the knot will lie deep to the fascia. Alternatively, many surgeons favour a loop suture and a knot is avoided. Each suture should be placed so that it lies no more than 1 cm advanced from the previous suture and the needle should be inserted 1 cm from the cut edge (Figure 13.6). If the incision has entered the rectus sheath, the anterior sheath may retract and great care must be taken to include it in the sutures, as this is the most important layer for the strength of the wound. The temptation to pull the suture tight must be resisted as this strangulates the tissue. The suture should only be as tight as is required to hold the edges in apposition. If these rules are followed, the total length of suture material used will be at least three times the length of the incision. Two or three lengths of suture will be required for a long midline incision. An Aberdeen knot (see Chapter 1, p. 3) may be used to tie the suture at the end of a continuous suture, but a more satisfactory method is to start a second suture from the opposite end and tie the two ends together where they meet. A non-absorbable knot outside the fascia can be troublesome in a thin patient. Again, it is possible, by finishing the suture on the inside, to tie a knot that will lie under the fascia. Alternatively, the cut ends of a knot could be passed under an adjacent suture to hold it lying flat.

The midline incision only became universally popular with the development of inert non-absorbable suture material, such as nylon, and slowly absorbable synthetic material such as PDS. Silk was never popular for abdominal wall closure after gastrointestinal surgery since, if a wound infection developed, healing did not occur until all infected braided suture material was removed. When catgut, which lost its tensile strength within 2 weeks, was in general use for abdominal closure, burst abdomens and incisional herniae were a relatively common complication of midline wounds.

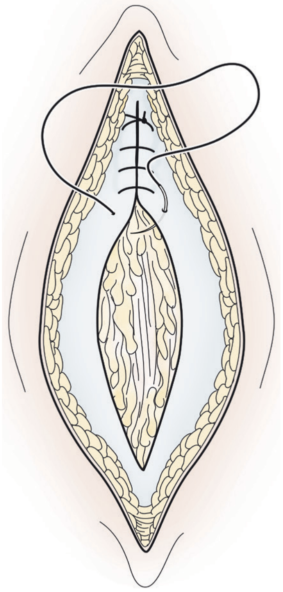

Figure 13.6 *Wound dehiscence and incisional herniae can be largely avoided by meticulous closure of the abdominal wall. The sutures must not be pulled tight. They must be suitably spaced at a maximum of 1 cm apart. Each tissue bite must be of adequate strength, and the suture should be introduced about 1 cm from the cut edge.*

Suprapubic incisions

Suprapubic incisions are lower abdominal midline incisions, but the initial skin incision is transverse just above the pubis. The skin and subcutaneous tissue are reflected up, off the anterior rectus sheath, and the linea alba incised vertically. The peritoneum can then be entered or the pre-peritoneal space developed distally for prostate and bladder access. This skin crease scar has advantages over a lower midline skin incision, which may contract and irritate.

Pfannenstiel incisions

Pfannenstiel incisions are transverse skin and anterior rectus sheath incisions but the rectus muscles are separated in the midline. The curved skin incision, convex downwards, is centred a few centimetres above the pubis. After division of the anterior layer of the rectus sheath in line with the skin incision, the sheath is dissected off the rectus muscle and reflected upwards (Figure 13.7). The rectus muscles are separated in the midline and retracted to expose the transversalis fascia and the peritoneum, which are divided in the midline. The rectus muscles may be separated as far as the umbilicus, but in this case the posterior rectus sheath will need to be divided too. Care must be taken to close the posterior rectus sheath or an incisional hernia may develop near the umbilicus. The transverse anterior rectus sheath incision is closed separately. These incisions afford good access to the pelvis with an unobtrusive scar but at the cost of altered sensation of the lower abdominal skin.

Paramedian incisions

Paramedian incisions provide broadly similar access to midline incisions, but they are no longer in regular use. They were favoured for their additional strength when catgut was

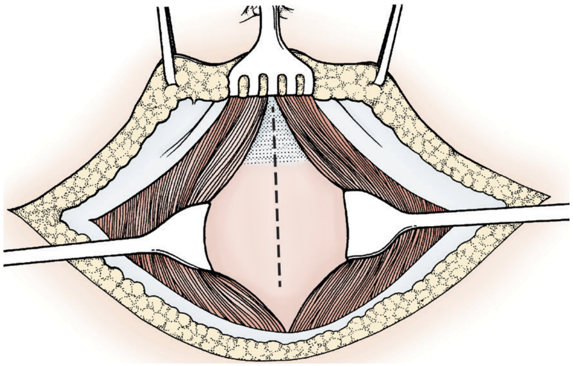

Figure 13.7 *A Pfannenstiel incision. The anterior rectus sheath is divided transversely and elevated with the skin. The recti are separated and the abdomen entered vertically.*

the suture material used for abdominal wall closure. The paramedian skin incision avoids the challenges posed by the umbilicus, and is deepened down to the fascia of the anterior layer of the rectus sheath. This is incised in line with the skin incision to expose the rectus muscle, which is displaced laterally, thus preserving its innervation. The muscle must be released from the sheath where it is tethered at the tendinous intersections. The posterior sheath is exposed and then divided in line with the anterior incision and the peritoneum is opened as described above.

Closure of a paramedian incision is undertaken in two layers. After the posterior sheath has been repaired, the rectus muscle is released back into its original position before the anterior sheath is sutured. The muscle lies between the two suture lines and may give some strength to the closure (Figure 13.8). The additional tension sutures in this old illustration underline the concern over dehiscence when catgut was in routine use.

Muscle-splitting incisions

Muscle-splitting incisions provide limited access but sufficient for an appendicectomy, as the appendix and part of the caecum can be delivered out through the incision. The gridiron and Lanz incisions (see Figure 13.4) differ in their skin alignment, but the deeper aspects of the incisions are similar. The external oblique aponeurosis is divided in line with its fibres to expose the fleshy internal oblique. Internal oblique and the underlying transversus are split in line with their fibres by blunt dissection (Figure 13.9). Retraction displays the peritoneum, which is entered as described above. If more extensive access becomes necessary, the incision may be extended upwards and laterally by converting it to a muscle-cutting incision and dividing internal oblique and transversus in line with the external oblique division. Alternatively, medial access can be increased by dividing the lateral edge of the rectus sheath. This allows wider separation of the internal oblique and transversus muscles, and the rectus muscle can be displaced medially (Figure 13.10).

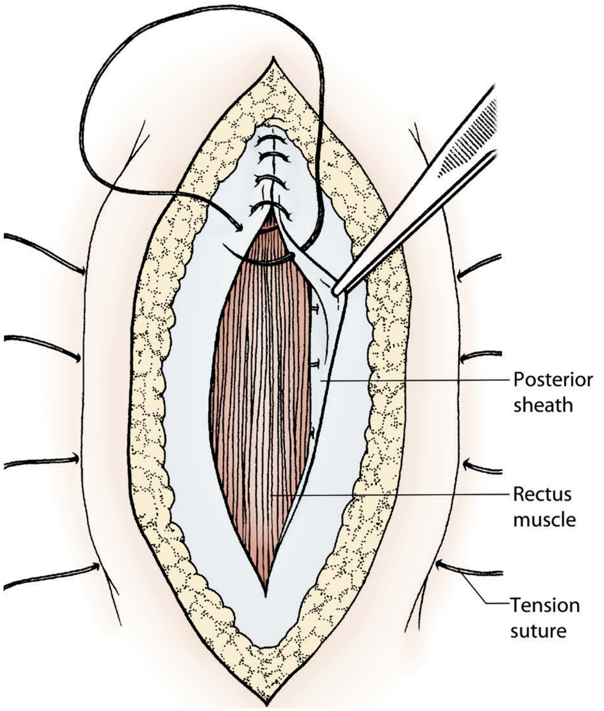

Figure 13.8 *The posterior sheath of this paramedian incision has been closed and the rectus muscle returned to the neutral position where it will lie between the two suture lines, giving support to the catgut closure. Note the additional 'tension sutures'; these were another feature of abdominal wound closure prior to the availability of modern suture materials.*

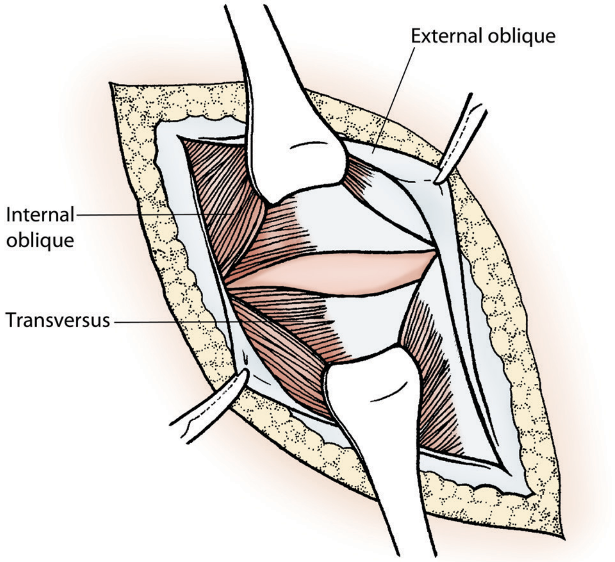

Figure 13.9 *An appendix muscle-splitting incision. The external oblique aponeurosis has been split in line with its fibres. The internal oblique and transversus are split between muscle bellies in a more or less transverse direction, and held apart by retractors to expose transversalis fascia and peritoneum.*

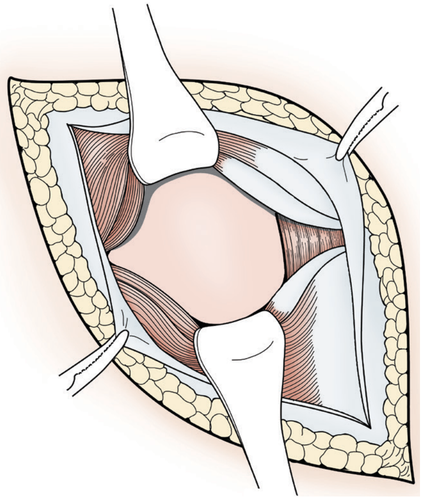

Figure 13.10 *Division of the lateral edge of the rectus sheath may be a useful manoeuvre to enlarge an appendix incision.*

Closure of appendix incisions is performed in layers. The peritoneum is closed first with a continuous absorbable suture. One or two loose absorbable sutures appose the muscles and finally the external oblique is closed with a continuous or interrupted absorbable suture (Figure 13.11). Even when catgut was routinely used for these wounds, incisional herniae were very rare.

Muscle-cutting incisions

Muscle bellies are divided in line with a transverse or oblique skin incision. Diathermy division reduces blood loss from small vessels, but larger vessels require individual ligation.

A *long transverse muscle-cutting* incision, either just above or below the umbilicus, provides good access to most of the abdomen, but this is partially dependent on patient build. Access is superior in those with a short wide abdomen and a wide costal angle (see Figure 13.4). Access to the oesophageal hiatus and the pelvis is, however, usually inferior to that obtained with a long midline incision. Postoperative pain is restricted to fewer dermatomes, and the avoidance of an upper abdominal wound results in better respiratory effort. The final transverse scar is unobtrusive.

In *infants*, transverse incisions are preferable to midline incisions. The abdominal muscle bulk is small, the abdomen is short and wide and the costal angle is obtuse, allowing easy access to the diaphragm. The pelvis is poorly developed in infancy, and pelvic access is not made any more difficult by a transverse approach. A transverse scar is cosmetically superior, especially as a vertical scar forms a ‘contracture’ as the child grows. In neonatal abdominal surgery the vessels associated with the placenta may still be patent and require formal ligation. The umbilical vein lies in the midline above the umbilicus, initially between the linea alba and the peritoneum, before turning deep to run towards the liver in the free edge of the falciform ligament. The umbilical arteries lie either side of the midline below the umbilicus and converge towards the umbilicus from their origin from the internal iliac arteries. They lie between the peritoneum and the abdominal wall muscles.

Oblique subcostal muscle-cutting incisions provide good access on the right for liver, biliary and renal surgery, and on the left for splenic and renal surgery. The angulation of the incision overcomes the limitations imposed by a narrow costal angle, but several abdominal nerves are divided. A bilateral subcostal (chevron or rooftop) incision is in essence a modification of a transverse incision and gives excellent access to the upper abdomen, although many of the advantages of a transverse incision at the level of the umbilicus are lost.

Oblique iliac fossa muscle-cutting incisions are similar to the appendix incisions except that internal oblique and transversus are cut in the same axis as the incision through external oblique. The peritoneum can then be opened to expose the sigmoid colon or swept medially for access to the ureter or iliac vessels.

Loin incisions are posterior oblique muscle-cutting incisions. Posteriorly, latissimus dorsi, serratus posterior inferior and quadratus lumborum replace the external and internal oblique muscles of the more anterior incision (Figure 13.12). If the incision is *subcostal*, posterior division of the renal fascia gives access to the retroperitoneal fat (Figure 13.13) and the peritoneum is swept away anteriorly. A *supracostal* incision along the superior border of the 10th, 11th or 12th rib will usually give good access to the kidney or adrenal. Alternatively, the incision may be through the bed of the lowest palpable rib – the 12th, or the 11th if the 12th is rudimentary. The periosteum over the rib is exposed and incised. The rib is freed subperiosteally and then divided near its angle

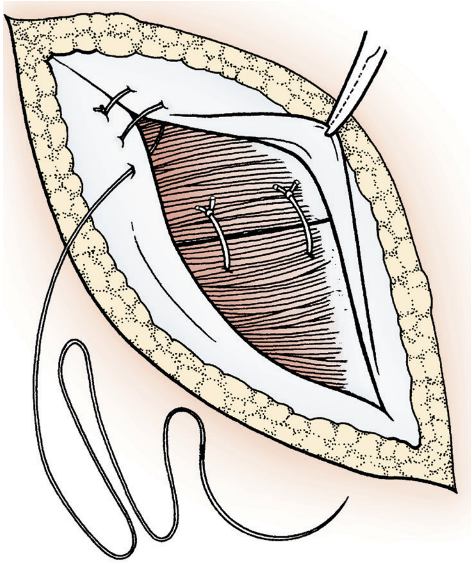

Figure 13.11 *Closure of an appendix incision is in layers. The muscle sutures must be loose in order to avoid tissue strangulation.*

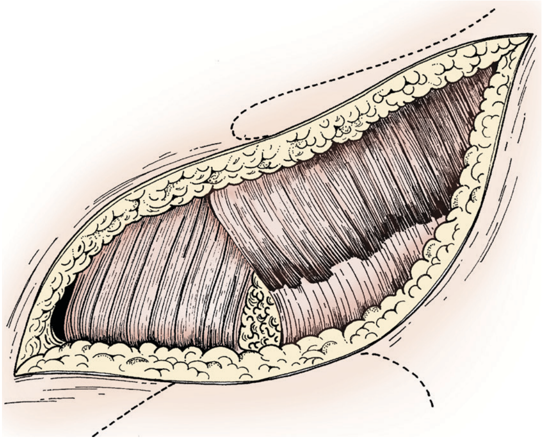

Figure 13.12 *The oblique loin incision exposes the external oblique muscle anteriorly and the latissimus dorsi posteriorly. These are divided in line with the skin incision to expose the second layer of musculature, the division of which exposes the renal fascia.*

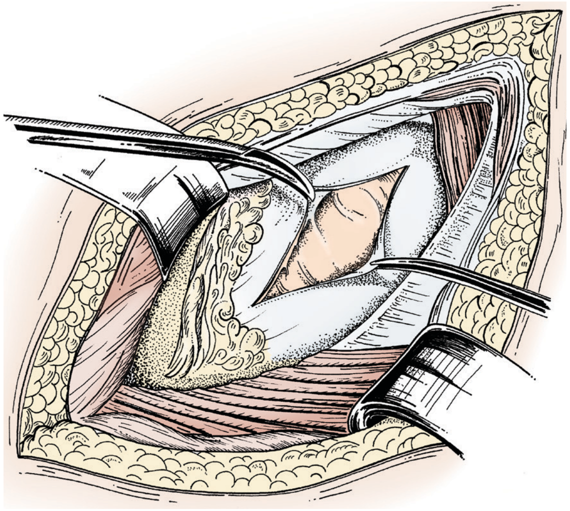

Figure 13.13 *The renal fascia is incised posteriorly so that it is not confused with the peritoneum, which is swept away anteriorly as the perinephric fat is entered.*

and the anterior part removed. Incision of the bed of the rib gives access into the retroperitoneal space. If the incision is at the level of the 10th rib, access can be increased by conversion to a *posterior thoracoabdominal incision*. The thoracic component of the incision is deepened and the pleura opened. The diaphragm is incised in line with the incision.

A further alternative in the loin is the *lumbotomy*, in which a vertical incision is made from the lowest rib to the iliac crest along the lateral border of erector spini, and deepened through muscles and fascia into the retroperitoneal space (Figure 13.14).

Closure of all muscle-cutting incisions is usually in two layers, using a continuous suture. The inner layer consists of peritoneum, transversalis fascia, transversus and internal oblique muscles – or the more posterior equivalents – along with the posterior rectus sheath. Most surgeons prefer to use an absorbable suture for this layer. The outer layer consists of external oblique and the anterior rectus sheath and normally incorporates a variable portion of the rectus muscle. This layer should be closed either with non-absorbable material or with an absorbable suture that retains tensile strength for several weeks. The covering fascia of the muscles has more strength than the muscle fibres and should always be included in the bites. Sutures must not be overtightened or muscle strangulation occurs.

Anterior thoracoabdominal incisions

Anterior thoracoabdominal incisions provide simultaneous access to the abdomen and chest. Division of the costal margin impairs postoperative respiratory function, and these incisions have now been almost abandoned in favour of a transdiaphragmatic or transhiatal approach from the abdominal incision (see Chapter 17). If this access is inadequate, most surgeons would now opt for a separate lateral thoracotomy. In the classic thoracoabdominal incision (Figure 13.15) the oblique, muscle-cutting abdominal incision crossed the costal margin and continued along the 8th interspace. The diaphragm can be divided radially from the costal margin towards the hiatus or it can be divided circumferentially 2 cm in from the chest wall, thereby preserving its innervation and leaving a cuff of diaphragm for reattachment. Careful diaphragmatic closure is essential to prevent an iatrogenic diaphragmatic hernia.

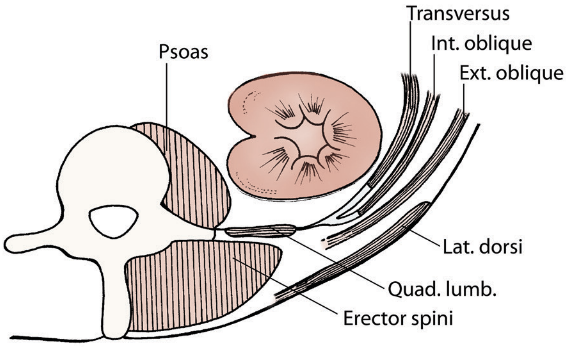

Figure 13.14 *The lumbotomy incision. The vertical incision through latissimus dorsi exposes the free posterior edge of external oblique. This is retracted forwards to expose the fused layers of the lumbodorsal fascia. Division of this layer exposes the renal fascia.*

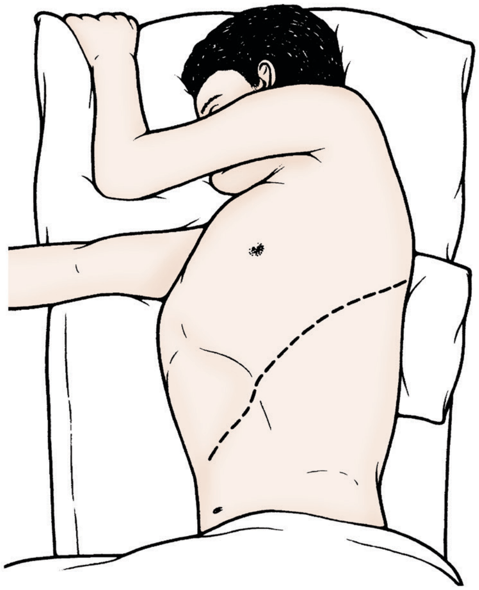

Figure 13.15 *Thoracoabdominal incisions give good simultaneous access to chest and abdomen, but division of the costal margin carries significant morbidity.*

LAPAROSCOPIC ACCESS

Intraperitoneal laparoscopic surgery

The first step in intraperitoneal laparoscopic surgery is the safe establishment of access to the peritoneal cavity. A pneumoperitoneum creates the space within which the surgeon works with high-quality visualisation from a light source and a video camera. The initial port is frequently inserted at the umbilicus, but it may be situated elsewhere if no umbilical port is required for the procedure or to stay clear of adhesions from previous surgery. Left upper quadrant placement of the first port may be useful, as this area often has few adhesions and fewer vulnerable intra-abdominal structures. Pneumoperitoneum is created by insufflation of CO_2 to a specified pressure. Usually, 12 mmHg is sufficient to give a working space in a fully relaxed patient and while higher pressures are used, they can interfere with ventilation.

Initially, blind puncture with a Veress needle through the linea alba was the favoured technique, but this has been abandoned by many surgeons owing to concerns over the risk of damage to the bowel, and in slim patients to the aorta and iliac vessels.[2] However, randomised controlled trials in a recent Cochrane review have not shown a difference in safety between open and closed techniques[3] and establishment of pneumoperitoneum with a Veress needle remains in use, particularly in obese patients where open access is difficult. In the open establishment of pneumoperitoneum the umbilicus is grasped at its base and everted. A 1–2-cm incision is created in the umbilical pit that allows the linea alba to be picked up with artery forceps. The linea alba and peritoneum are then opened by the same technique that is used for an open laparotomy. The first port trocar is introduced and used to insufflate CO_2. Insertion of a transparent trocar, within which the laparoscope can be used to give a direct view of the progress of the trocar through the tissues of the abdominal wall, is an alternative method for initial port placement and may be particularly useful in obese patients.[4]

Once pneumoperitoneum is established, the camera is inserted. Insertion of the subsequent ports is much safer as the abdominal wall is lifted forwards away from the bowel by the pneumoperitoneum and, in addition, the points of the trocars can be viewed from within as they pierce the parietal peritoneum. On each occasion a small incision of skin alone is made prior to the introduction of the port with a sharp trocar. These ports are pushed through the abdominal wall with a twisting motion. Initially, they should be placed perpendicular to the abdominal wall or angled slightly towards the operating field, but once the tip of the trocar has pierced the parietal peritoneum, it should be angled in a safe direction away from intra-abdominal structures and pushed fully into the abdomen.

SELECTION OF PORT SITES

The size, position and number of subsequent ports depend not only on the surgery to be performed but also on the preference of the surgeon. Most laparoscopic instruments can be introduced through a 5-mm port, but 10-mm laparoscopes give a better view than 5-mm ones and many laparoscopic stapling devices need a 12-mm port. Ports that are positioned too close to each other will result in intraperitoneal clashing of instruments. Instruments that are introduced through the ports should ideally converge in the surgical field at an angle of between 60 and 90 degrees to ensure maximum manoeuvrability. The camera port and the two instrument ports used by the operating surgeon should form an equilateral triangle with the camera port furthest away from the operating site. Position of the port sites can be adjusted for cosmetic considerations or to use the site of a planned stoma. If difficulties are encountered during a case, additional 5-mm ports carry little extra morbidity. At the end of the procedure the port sites of 5 mm and less require only skin closure, but fascial closure of the larger port sites is important. The umbilical port site is a common site of incisional hernia if closure of the fascia has not been optimal.

Extraperitoneal laparoscopic surgery

An extraperitoneal minimal-access approach is an alternative to open surgery for most retroperitoneal structures. In some areas direct gas insufflation can create a disappointingly small space if the gas tracks over a wide field and fails to disrupt the tough fibromuscular septa within the fat. A balloon technique to create a larger, more localised space can be used. A transparent balloon into which the laparoscope is passed is an adaption that allows the work space to be created under direct vision.

Groin access for extraperitoneal inguinal hernia repair is through an initial 10-mm port established by a 1–2-cm transverse incision just below the umbilicus. A transverse incision is then made in the anterior rectus sheath just to one side of the midline. The medial edge of the rectus muscle is retracted laterally to expose the fibres of the posterior sheath. The laparoscope is inserted under the rectus muscle and gas insufflation commenced. The laparoscope is then introduced and advanced. The posterior sheath forms a barrier to inadvertent deep insertion until the laparoscope emerges into the true extraperitoneal space below the arcuate line. Two further 5-mm ports are then established.

COMPLICATIONS FROM ABDOMINAL WOUNDS

Wound infections

Wound infections after gastrointestinal surgery have been reduced by the administration of prophylactic antibiotics. When there is an established infection, it will occasionally settle with antibiotic therapy, but frequently there is an infected haematoma, which requires drainage. If the infected collection is subcutaneous, the skin scar can be disrupted easily, and virtually painlessly, at this early stage of healing. The wound must be opened over a sufficient length so that there is no residual infection deep to intact skin. Resuturing is sometimes considered once the wound is clean, but is seldom necessary as the open wound heals surprisingly quickly. A wide skin scar can be revised if the final appearance is unsatisfactory.

Deep wound infections within the abdominal muscles often require formal re-exploration for drainage of pus. Systemic antibiotics are indicated and the surgeon must be alert to the dangers of a necrotising infection in the abdominal wall (see Chapter 4, p. 49). Occasionally, what appears initially to be a simple wound infection quickly declares itself as an intestinal cutaneous fistula as intestinal contents drain through the wound. This may have occurred secondary to an anastomotic breakdown or from damage to a loop of bowel during the dissection or the abdominal closure. If there is no evidence of generalised peritonitis, exploration and repair should be delayed; the surgical management of such fistulae is discussed in Chapter 23, p. 430.

Burst abdomen

This once common complication is now rare and is almost exclusively an indication of faulty technique. A poorly tied knot may have slipped or the knot may have damaged the suture material, which subsequently fractured. The suture may have been pulled too tight and cut through the tissue or the suture may have been carelessly sited and the fascia not included in the bites. The patient is usually making slow progress with a prolonged ileus. At around 7–10 days postoperatively, leakage of clear or serosanguineous fluid from the wound is the first ominous sign of incipient dehiscence. The fluid is from within the peritoneal cavity and leaks because the deep layers of the wound have already separated. Often it is the removal of the skin sutures that allows the dehiscence to manifest and loops of bowel are extruded. Treatment consists of protection of the exposed bowel during a short period of fluid and electrolyte resuscitation. The patient should be returned to the operating theatre as soon as possible for secondary closure of the abdomen. Abdominal compartment syndrome may be of concern and, in exceptional circumstances, it may be preferable to manage the situation with temporary abdominal containment or to leave the abdomen open as a laparostomy.

Incisional herniae

Incisional herniae may become apparent during the early months after surgery when there has almost certainly been some deep wound dehiscence in the postoperative period. A poor-quality fascial scar, as a result of a wound infection or faulty closure technique, may disrupt later, however, and both morbid obesity and chronic cough greatly increase the risk.

TEMPORARY ABDOMINAL CONTAINMENT AND LAPAROSCOPY

Occasionally, it is impossible to close the abdomen because of a temporary increase in volume of the abdominal contents due to oedematous bowel or a retroperitoneal haematoma, or there may be packs to control bleeding, which have reduced the available intra-abdominal capacity. Abdominal closure under tension should not be attempted, as the increased pressure embarrasses respiratory function and intra-abdominal perfusion. In addition, sutures may cut through and wound dehiscence is likely (see Chapter 12). A permanent mesh may be considered, but this may be unnecessary for a temporary situation or contraindicated because of sepsis. A temporary container for the viscera can be constructed by sewing an intravenous fluid bag to the edges of the laparotomy wound[5] and the closure delayed for up to a week. These simple ‘Bogota bags’ have been largely superseded by commercially available vaccuum-assisted closure (VAC) devices.

Gross intraperitoneal sepsis and fistulae may make any attempt to close an abdomen impossible. Consequently, the abdomen can be left open for several weeks while the sepsis is controlled, although such patients will require intensive care and often also respiratory support. When the abdomen is left open in this fashion it is described as a *laparostomy*. VAC devices have made the management of this situation easier, although there is still some concern that they may increase the risk of fistulation.[6] Where commercially manufactured VAC dressings are too expensive, adaptations using similar principles have been successful.[7]

ABDOMINAL WALL HAEMATOMA

Spontaneous rupture of an inferior epigastric artery results in a rectus sheath haematoma, and patients receiving anticoagulants are at increased risk of this condition. The tender abdominal mass can cause diagnostic confusion. Surgery is seldom indicated as there is a tamponade effect on the vessel from the blood clot. However, absorption of clotting factors within the haematoma may cause further derangements in blood clotting, with an ensuing ‘vicious circle’. Anticoagulation will require to be reversed, clotting monitored and consideration given as to whether to evacuate the haematoma or to treat the patient conservatively.

RECTUS ABDOMINIS FLAPS

The rectus abdominis myocutaneous flap is a versatile tool for reconstruction of the breast, chest wall and perineum. The muscle can be used on its own or with an ellipse of overlying anterior rectus sheath and abdominal skin to replace perineal or breast skin loss. The skin ellipse, if required, is incised first. For perineal or sternal reconstruction, a vertical skin ellipse is frequently used, and the flap is described as a vertical rectus abdominis myocutaneous (VRAM) flap. For breast reconstruction, a transverse skin ellipse is preferred, and the flap is described as a TRAM flap. The muscle above and below the skin ellipse is then exposed by a paramedian incision through the anterior rectus sheath. The whole muscle can be used or only part of its width. The muscle is freed from the sheath at its tendinous intersections.

If the muscle is to be rotated into the pelvis, both the insertion and the origin of the muscle are divided, but great care must be taken to preserve the deep inferior epigastric vessels entering the muscle from below. For breast reconstruction the flap may be rotated upwards on the superior epigastric pedicle. However, this artery, which is the continuation of the internal thoracic artery, is relatively small and the blood supply more precarious. For this reason, and to avoid the epigastric bulge caused by tunnelling of the pedicle, a free TRAM flap is preferred by some breast surgeons. It is raised on the larger deep inferior epigastric artery and a microvascular anastomosis performed onto an artery in the axilla or onto the internal thoracic vessels.

A transverse skin ellipse can also be raised as a free flap, leaving the entire muscle behind. The small perforating vessels, on which the skin perfusion depends, are traced through the muscle to the main artery. This requires training, skill and magnification. The flap is described as a deep inferior epigastric artery perforator (DIEP) flap.

ABDOMINAL WALL HERNIAE

Spontaneous herniae of the abdominal wall occur most frequently in the midline and in the groin. Incisional herniae may develop in any surgical scar, and thus are also common in the midline. The surgical management of groin herniae, both inguinal and femoral, is discussed in Chapter 25, while hiatus herniae are discussed in Chapter 18.

Most herniae have a sac of parietal peritoneum into which any mobile intraperitoneal structure may herniate. Some small herniae – of which epigastric herniae are the commonest examples – initially have no sac and consist solely of extraperitoneal fat. A sac is only acquired if the hernia later enlarges. Many large herniae have both a sac and a significant extraperitoneal component, which may consist solely of extraperitoneal fat but may also include a partially extraperitoneal viscus such as the bladder, caecum or sigmoid colon. These sliding herniae are particularly common in the groin (see Chapter 25).

A patient may request repair of a hernia for either comfort or cosmesis, or a surgeon may recommend repair because of the risk of strangulation. As many patients are elderly or unfit and somewhat reluctant to have unnecessary surgery, the surgeon must consider the risks in each individual case.

A hernia is said to be strangulated when the tissue that has herniated is constricted in such a way as to diminish its blood supply. The constriction may be from the edges of the fascial defect, in which circumstances any extraperitoneal tissue is also vulnerable. More often, the constriction is from the narrow neck of the peritoneal sac. A third point of potential constriction is by the neck of a peritoneal loculus within a sac. This most often occurs in a multiloculated para-umbilical hernia. The risk of strangulation is greatest in narrow-necked sacs and these herniae are usually difficult to reduce. The danger associated with strangulation is dependent on the tissue involved. A strangulated knuckle of extraperitoneal or omental fat is relatively harmless compared with an infarcted knuckle of small bowel or colon. Strangulated herniae with gut ischaemia or infarction are discussed in Chapter 23.

Hernial repair requires closure of the fascial defect. This may be achieved by sutured apposition of the fascial edges or the defect can be bridged with alternative tissue or with prosthetic material.

MESH ABDOMINAL WALL REPAIR

The development of inert meshes, such as monofilament polypropylene, has greatly simplified the treatment of most difficult herniae. Laparoscopic repair is routinely achieved with mesh and increasingly mesh is also used in open repairs. A mesh may be used over (on-lay) or under a simple repair to provide additional strength. The mesh must be placed so that it is in contact with normal tissue for some distance on either side of the closure, and a few sutures or staples are then used to prevent it becoming displaced in the immediate postoperative period. Ultimately, the mesh becomes incorporated into the tissues and adds greatly to the strength of the final scar.

Alternatively, a mesh may be used to bridge a defect in the abdominal wall that cannot be closed without unacceptable tension. The ideal position for such a mesh is between the closed peritoneum and the abdominal wall, where intra-abdominal pressure pushes it against the muscles and fascia and the peritoneum separates it from the bowel (Figure 13.16). This is only possible if the peritoneum can be separated from the overlying muscles and sufficient peritoneum from the sac can be saved to allow peritoneal closure. Unfortunately this situation is often unattainable and the mesh has to be placed intraperitoneally, in direct contact with bowel, if omentum cannot be placed between. Although there was initial concern that this might increase the risk of fistula formation and mesh infections, subsequent studies were reassuring.[8]

A mesh should be several centimetres larger than the defect it will replace, as it is only in the areas of overlap that it can be incorporated into tissue and provide any inherent strength. An extraperitoneal or an intraperitoneal mesh first requires at least four sutures or staples (as shown in Figure 13.16) to prevent any rolling of the edges of the mesh. Larger intraperitoneal meshes require more tethering as there is a potential for herniation of abdominal contents between the mesh and the parietal peritoneum. Open access for this additional tethering can be difficult, but laparoscopically it is straightforward. In an open repair, the edges of the fascial defect are then sewn with a continuous non-absorbable suture down onto the top surface of the mesh, with care being taken to prevent injury to any underlying viscus.

Any implanted mesh may become infected. The infection is difficult to eradicate, as bacteria may be in a protected

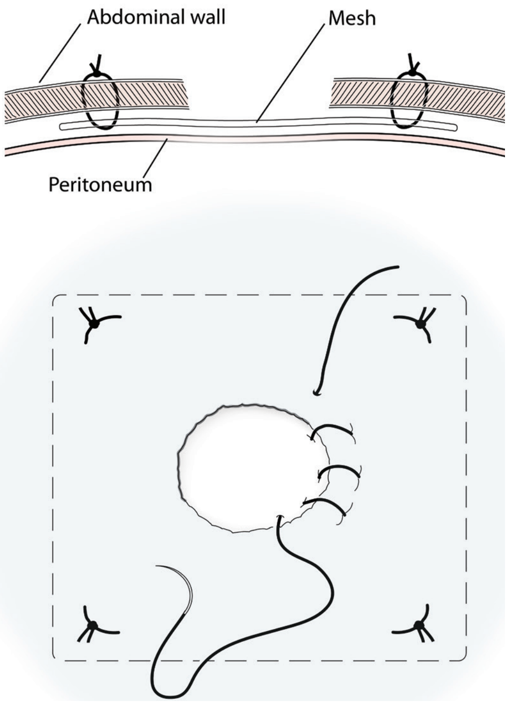

Figure 13.16 *The ideal position for a mesh is between the closed peritoneum and the partially deficient abdominal wall. The mesh should be considerably larger than the defect so that there is overlap with strong healthy tissue. Four sutures will prevent the mesh edges from rolling, after which the edge of the abdominal defect is sewn to the top surface of the mesh, with care being taken to avoid injury to any underlying bowel.*

environment where there is poor antibiotic penetration and in spaces too small to allow access to neutrophils. Recent advances in mesh material and pore size have improved this problem, but the surgeon should still be very wary of using a mesh in any potentially infective situation, and antibiotic cover is always recommended. At open surgery, a vacuum drain in the subcutaneous fat reduces the risk of a haematoma as a potential culture medium for infection. An infected non-absorbable mesh almost always has to be removed completely.

Smooth inert patches of expanded polytetrafluoroethylene (ePTFE), marketed as Gore-Tex®, are an alternative to polypropylene meshes. The reduction in fibrosis may decrease bowel complications when the mesh has to be in direct contact with the bowel, but the poor tissue in-growth inevitably results in a weak attachment of the patch to the abdominal wall and a greater risk of recurrence. Compound meshes with an inner layer of ePTFE and an outer layer of polypropylene may have a role.

Inert collagen meshes (acellular dermal matrices) are increasingly used in the presence of infection. They can be of great value in bridging a fascial defect left when an infected mesh has had to be removed. However, as this material is extremely expensive, its use continues to be limited to situations where other techniques are inappropriate.

OPEN ABDOMINAL WALL HERNIA REPAIR

Preoperatively it is helpful to mark on the skin the exact position and size of the defect and, in addition, the perimeter of the swelling when the hernia is at its maximum size. These marks can serve as a useful guide during the dissection. When the hernia is large an elliptical excision will remove redundant overlying skin. The subcutaneous fat is incised until the peritoneum of the sac, or its covering of extraperitoneal fat or thinned fascia, is encountered. The plane is then developed between this and the surrounding subcutaneous fat. This plane will lead to the edges of the fascial defect, which can then be defined. It is helpful at this stage to clear the subcutaneous fat off the fascia for a few centimetres around the defect to aid the subsequent repair (Figures 13.17 and 13.18). If there is stretched fascia over the hernia, this is divided at the junction with the healthy tissue at the edge of the defect. If the sac is still complete, it should be opened at this stage unless it is wide-necked and the surgeon is sure it is not multiloculated. Any intraperitoneal viscus adherent to the sac is freed and returned into the abdomen, and it may be necessary to enlarge a small defect to achieve this. The redundant sac is excised and the abdominal defect is closed with interrupted or continuous sutures, a non-absorbable variety being preferable. There is often no plane between the peritoneum and the abdominal fascia, and both layers may be closed together. If, however, the peritoneum separates from the abdominal wall musculature, it may be closed as a separate layer. If the edges of the defect cannot be apposed without tension, a mesh should be used as discussed above. Any significant dead space in the subcutaneous fat should be obliterated with sutures. A subcutaneous vacuum drain should be considered.

LAPAROSCOPIC ABDOMINAL WALL HERNIA REPAIR

Increasingly, a laparoscopic approach is used for the repair of anterior abdominal wall herniae. Although for small umbilical and epigastric herniae an open operation is still a more

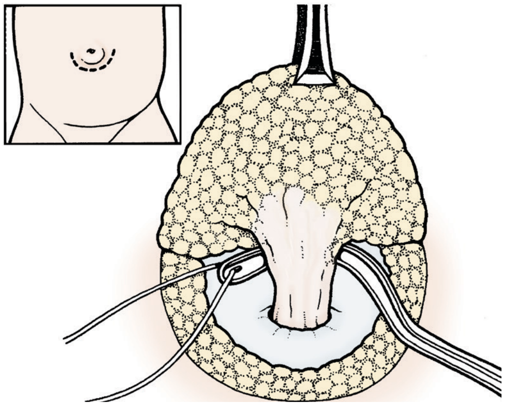

Figure 13.17 *Umbilical hernia. The fascia around the defect has been cleared of fat in preparation for the repair. The fascial covering of the sac is divided at its junction with the linea alba.*

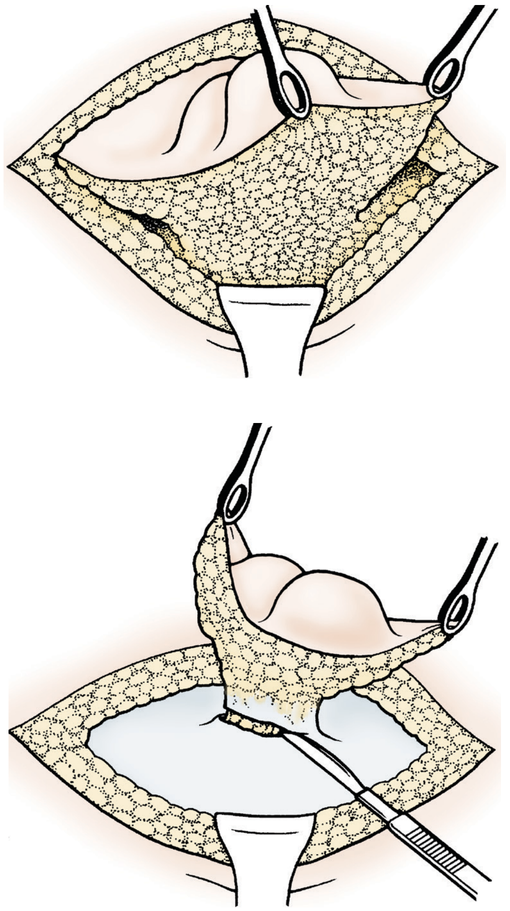

Figure 13.18 *The stretched ellipse of skin overlying this para-umbilical hernia and adherent to the fundus of the sac will be excised. The sac is entered at the junction of the fascia and the stretched coverings at the neck of the sac.*

minor undertaking, a laparoscopic approach to the repair of a large para-umbilical or incisional hernia has significant advantages. The umbilicus is commonly involved in the hernia and the first port must be established at a different site by the techniques described above. The contents of the sac are reduced into the abdominal cavity. This may happen spontaneously with the establishment of the pneumoperitoneum, but if the contents remain stuck in the hernia, they should be dissected out with care to avoid any injury to the bowel.

The mesh is rolled up and delivered down the first port site and unfurled in the peritoneal cavity. It is laid over the hernial defect with a generous overlap onto the peritoneum surrounding the defect. Positioning of the mesh can be aided with one or more temporary sutures tied to the mesh extracorporeally prior to inserting it into the peritoneal cavity. Once the mesh is unfurled, the straight needles on these sutures are passed through the anterior abdominal wall and grasped with artery forceps where they emerge through the skin. Traction on these sutures lifts the mesh into position. The mesh is secured in place with staples, every few centimetres around the perimeter, and any retaining sutures are then cut flush with the skin. The potential space of the unresected hernial sac almost inevitably fills with serous fluid, but the seroma resolves spontaneously over 8–12 weeks. Concern over leaving mesh in contact with small bowel has led some surgeons to favour placing the mesh extraperitoneally. This is a more demanding technique, as the peritoneum must be incised lateral to the defect, mobilised away from the anterior abdominal wall and then replaced over the mesh after it has been secured.

The operative details, especially if an open approach is used, vary for each type of hernia, and the operations are described in more detail below.

Epigastric hernia

These midline herniae occur between the umbilicus and the xiphisternum. They occur at all ages and are also seen in infancy. Epigastric herniae are often no more than a small protrusion of extraperitoneal fat through a defect in the linea alba, but larger herniae may contain a peritoneal sac. These small herniae are often irreducible as the knuckle of fat is trapped by the edges of a very small defect in the fascia. Repair is through a vertical or transverse incision. The fatty protrusion, and sac if present, are ligated and excised; the defect in the linea alba is then closed by one or more sutures.

Umbilical hernia

A true umbilical hernia occurs through a circular defect at the umbilical cicatrix, and causes a symmetrical protrusion of the umbilical skin. Umbilical herniae are common in infancy and reduce easily. If ignored, many congenital umbilical herniae close spontaneously, and this is a safe policy as strangulation is very uncommon in children. Those still present at 4 years of age are unlikely to close and will require surgical repair. A similar hernia is seen in many women in late pregnancy and may disappear after delivery. A small irreducible umbilical hernia is often encountered as an incidental finding in an overweight man. These are plugged with omentum and, although there may be no immediate concern, there is a long-term risk of strangulation and surgery should be considered.

Repair of umbilical herniae in adults and children can be performed through an inconspicuous, small curved incision at the inferior edge of the umbilicus. The subcutaneous fat is divided to expose the linea alba and the medial edge of the rectus sheath on either side. The hernial sac protrudes through a circular opening in the midline, towards the apex of the umbilicus and is covered by a condensation of fascia that is continuous with the linea alba (see Figure 13.17). The junction of fascia and linea alba is defined circumferentially, and forceps are then passed round above the umbilicus to provide traction. The hernial sac rarely contains viscera but should nevertheless be opened with care. To achieve this, the fascia over the inferior half of the neck of the sac is first divided to expose the underlying peritoneum which, in turn, is opened and the interior of the sac inspected. Adherent omentum is released. The neck of the sac is then transected, leaving a circular defect in the linea alba and peritoneum, which can be closed in one layer in a transverse manner. A long-acting absorbable suture such as Vicryl™ or PDS® is suitable in children, although most surgeons would prefer a non-absorbable suture repair in an adult. Recurrence is common unless the fascia is closed meticulously and this has led some surgeons to use mesh routinely in adults. Infection of an umbilical mesh, however, remains a concern. A Mayo repair in which the fascia is overlapped is often counterproductive, as tension is increased. After repair, the final cosmetic appearance can be improved by fixing the apex of the umbilicus to the linea alba with a subcutaneous stitch to invert the umbilical cicatrix. The sac may be left *in situ* on the undersurface of the umbilical skin as it is densely adherent. Sometimes, a narrow-necked large sac will continue to evert the umbilicus, and this should be partially excised to allow flattening of the skin. If there is excessive redundant skin, this can be excised.

Para-umbilical hernia

Para-umbilical herniae are common in parous, obese, middle-aged and elderly women. As the risk of strangulation is high, surgery should usually be recommended. They occur most frequently through the linea alba just above the umbilicus, and are clinically differentiated from an umbilical hernia in that they displace the umbilicus by their asymmetrical protrusion, but do not evert and stretch the umbilical skin unless they become very large. However, at operation some are found to be large, true umbilical herniae and the umbilical skin has merely migrated distally with age, giving the appearance of a supra-umbilical swelling. Others are a compound defect in the fascia. The peritoneal sac is often irregular and loculated. Bowel may be trapped and strangulated within loculi, even though the linea alba fascial defect feels large and unlikely to cause trouble. Even in the presence of strangulation, the significance of the hernia may be overlooked as the cause of the intra-abdominal symptoms, as the bulk of the hernia is soft and reducible.

Open repair is through a transverse incision over the hernia just above the umbilicus, although it is sometimes preferable to make an elliptical excision to excise the redundant skin and even the umbilicus itself (Figure 13.18). The dissection down to the fascial defect and the clearing of fat off the surrounding fascia is performed in standard fashion. The sac and stretched fascia are excised at the edge of the defect. Even in a small wide-necked sac it is important to open the sac, free the omentum and bowel from loculi within it and excise the irregular peritoneum of the sac. If the abdominal wall defect is simply closed over a loculated sac, although the hernia has been repaired, the loculi remain as an area where bowel can be trapped and become strangulated. Not infrequently, these herniae consist of two adjacent defects with a narrow intervening strip of intact linea alba. This should be divided to create one defect before repair. The peritoneum may be closed as a separate layer or together with the fascia. Extension of the defect laterally aids closure, which is performed with interrupted non-absorbable sutures in a transverse direction, unless a longitudinal repair will result in less tension. Increasingly, surgeons are favouring the use of mesh in all para-umbilical hernia repairs even when there is no tension. The umbilicus is a potentially infected site, and antibiotic cover should be considered in all repairs; it is certainly mandatory if a mesh is to be used.

A laparoscopic repair has the advantage that an incision in the potentially infected umbilical skin is avoided and, as a mesh is planned from the outset that will occlude the neck of the sac, dissection to remove the loculated sac can be avoided. However, the initial release of small bowel trapped within loculi of the sac may be difficult.

A form of para-umbilical hernia also occurs in young children. These occur through a transverse elliptical defect in the linea alba just above the umbilicus and are synonymous with epigastric herniae. Strangulation is uncommon, but repair should be recommended as, unlike infantile umbilical herniae, they do not close spontaneously.

Intermuscular hernia

The most common of these relatively rare herniae is the *Spigelian hernia.* Herniation occurs only through the inner layer of abdominal musculature, and the sac enlarges in the plane between the layers of the abdominal wall. Diagnosis may be difficult as the hernia only produces a diffuse bulge, often in an obese abdomen, and the defect itself is seldom palpable. In a classical Spigelian hernia the neck of the sac is through a defect at the lateral edge of the rectus sheath at the level of the arcuate line, but other sites of herniation also occur. Even if an open repair is planned, an initial laparoscopy is sometimes helpful, both to confirm the diagnosis and to identify the site of the defect over which the incision should be centred.

Lumbar hernia

Lumbar herniae may arise spontaneously or as an incisional hernia after surgery. Complications are rare and surgery is seldom indicated.

Inguinal and femoral herniae

These are the most common of all abdominal wall herniae, and their surgical repair is described in the section on groin surgery (Chapter 25).

Obturator, gluteal and sciatic herniae

These herniae are all exceedingly rare. A palpable external swelling is even rarer, so diagnosis is usually at exploratory laparotomy or laparoscopy for small bowel obstruction when a loop of bowel is found to be trapped within a sac. Repair of these defects is therefore from within the abdomen after reduction of the hernial contents. It is occasionally difficult to deliver strangulated bowel from the obturator canal at laparoscopy, or even at laparotomy, and the sac can be approached from below by an additional vertical incision, 2 cm medial to the femoral vessels. The sac lies deep to adductor longus and pectineus. Closure of an obturator defect is difficult and the obturator vessels and nerve are easily injured by sutures. A simple, safe open technique consists of inversion and ligation of the sac, followed by incision of the peritoneum over the pecten pubis. The peritoneum is elevated to expose the obturator canal and a mesh placed in a retroperitoneal position covering the canal.[9] The mesh is secured superiorly to the pectineal ligament and medially to fascia over the pubis before the peritoneum is replaced and sutured (Figure 13.19).

Incisional hernia

The aetiology of incisional herniae has already been discussed. Easily reducible wide-necked defects may often be ignored. Some form of elasticated support for comfort is often all that a patient wishes, but if repair is planned it is important to decide whether only part of the wound or the whole wound needs to be explored. If there is more than one area of herniation, it is usually advisable to repair the whole wound. Accurate preoperative skin marking of the extent of the palpable sac and the fascial defect is helpful. Access for an open repair is via the original scar, and excision of the scarred skin gives a better cosmetic result. The sac is defined and the plane around it followed to the edges of the fascial defect. Dissection is then continued on the surface of the intact fascia for a couple of centimetres around the defect. The edges of the defect can now be defined by incising the junction of normal fascia with the attenuated fascial covering of the sac.

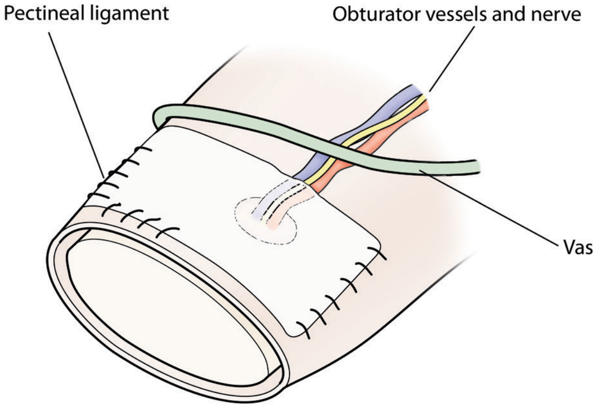

Figure 13.19 *The mesh lies in a pre-peritoneal position covering the obturator canal. Suture fixation is only to the pectineal ligament and the fascia of the pubis, thus avoiding injury to vital structures.*

A shallow peritoneal protrusion from most of a scar need not be opened, and to do so unnecessarily merely increases the risk of small bowel injury and of ileus. Therefore, if the peritoneum can be freed from the undersurface of the abdominal wall it can be left intact, and the fascia repaired over it. A peritoneal sac through a narrow defect should be excised, and the peritoneum should also be opened if there is any concern that a wide-necked sac could be loculated. More often, the peritoneum has to be opened because it cannot be separated from the abdominal wall, but this has the advantage that the surgeon has the opportunity to palpate the undersurface of the adjacent scar for weak areas that need to be repaired at the same operation.

If the peritoneum has been opened, it may be either closed separately or with the abdominal wall repair. The edges of the abdominal wall defect are excised so that there is a freshly cut edge of healthy tissue for closure. The suture technique used is similar to that for any abdominal wall closure as described above, but particular care must be taken to encompass healthy fascia in the suture bites. A non-absorbable continuous suture is suitable. If the abdominal wall has retracted laterally and there is any tension, then a mesh or other technique should be used. There is also increasing evidence that some form of mesh repair may be the better option, even when the surgeon is confident that satisfactory tension-free apposition of the fascia can be achieved by using a simple suture technique.[10] An on-lay mesh, placed over the closed fascia and secured to it with sutures, is the simplest technique. However, any superficial wound infection is likely to result in a chronic infection in the mesh. Vacuum drainage of the subcutaneous fat to prevent postoperative haematoma collection and prophylactic antibiotics will reduce the incidence of this complication.

Frequently, the fascial edges of an incisional hernia do not appose without tension and some form of mesh repair to bridge the defect is necessary. In a laparoscopic repair no attempt is made to appose the fascia and a mesh is planned from the outset.

Parastomal hernia

When a colostomy or ileostomy is performed there is a potential channel for herniation beside the bowel. These parastomal herniae are difficult to repair, and the stoma has often to be re-sited through another area of abdominal wall. These procedures are discussed further in Chapter 22.

ABDOMINAL WALL RECONSTRUCTION

Even though a collagen mesh can often solve the problem when repairing an abdominal wall defect in the presence of sepsis or fistulae, there are occasions when even this will be unsatisfactory, particularly when there is extensive loss of abdominal musculature, fascia and skin. Several alternative strategies are available.[11]

Reflected flaps of rectus sheath can be used to bridge the defect and numerous surgical variations have been described. In its simplest form an incision is made through the anterior rectus sheath around the hernial defect, some 5 cm distance from the edge. The anterior sheath is then elevated circumferentially off the muscle and folded medially to be used to close the defect.[12]

Component separation techniques are increasingly employed. Incisions are made that allow sliding between the layers of the abdominal wall muscles. First, a full-length vertical division of the external oblique is made, 2 cm lateral to the rectus sheath. This allows the rectus muscle to be drawn medially and an advance of as much as 10 cm at the level of the umbilicus can be achieved. This only becomes possible once the avascular bands between the external and internal oblique muscles have been released so that the muscles can slide over each other. A further medial advance of 2–4 cm can be procured by a similar full-length vertical division of the posterior rectus sheath.

Musculocutaneous and fasciocutaneous flaps can provide healthy tissue for the repair of large defects. Many different flaps can be brought to the defect by pedicled or free flap techniques, as described in general in Chapters 2 and 4. Tensor fascia lata flaps have proved the most versatile.

CONGENITAL ABDOMINAL WALL PROBLEMS

Umbilical hernia

This common condition is often appropriately managed by general surgeons with a paediatric interest, and the surgery is described above. However, a general surgeon should only operate on the conditions outlined below if no referral is possible.

Exomphalos

Exomphalos is a herniation of abdominal viscera through an abdominal wall defect into the base of the umbilical cord. The visceral contents are contained by a semi-transparent covering made up of peritoneum and amniotic membrane. The condition is arbitrarily divided into *minor* and *major* depending on whether the defect is smaller or larger than 5 cm. The contents of an exomphalos vary from a few coils of ileum to most of the abdominal viscera including liver, spleen, stomach, small bowel and colon. Malrotation is common and remnants of vitello-intestinal duct may persist. In two-thirds of babies there is an associated congenital abnormality. The magnitude of the surgical challenge therefore varies enormously. A minor defect with only a small visceral protrusion can be easily repaired. The sac is excised at the junction of membrane and skin and the umbilical vessels and urachus identified and ligated. The bowel is inspected for any other abnormality, returned to the abdomen and a simple sutured repair performed. A major defect, with considerable visceral protrusion, may be impossible to approximate immediately. Surgical options include closing the defect with skin alone and repairing the inevitable incisional hernia at a later date, or a staged repair using a temporary prosthesis. A pouch of Dacron™-reinforced silastic sheet is sutured to the defect, abdominal contents are then gradually reduced by daily tapering of the pouch and repair attempted around 10 days later. Historically, an alternative non-operative management was to await spontaneous epithelialisation of an intact exomphalos and to delay definitive repair of the abdominal wall defect. The application of mercurochrome to dry and toughen the sac is, however, inadvisable as absorption of mercury will occur, but this technique has been repopularised with the use of silver sulphadiazine dressings for exomphalos major.

Gastroschisis

Gastroschisis is often misdiagnosed as a ruptured exomphalos, but it is a separate entity. The gut has herniated through a defect adjacent to, and usually to the right of, the umbilical cord, but the bowel lies free as there is no covering membrane. The prolapse is normally limited to the midgut, which is oedematous, apparently short and covered with a fibrinous exudate. Prolonged intestinal dysmotility is the norm for several weeks and parenteral nutrition is therefore required. The incidence of associated anomalies is small and usually limited to intestinal atresia. There is no alternative to surgery as the bowel is exposed, but temporarily covering the extruded bowel with ‘cling film’ reduces heat and fluid loss during transfer to a specialist centre. At surgery the abdominal wall defect is enlarged, the bowel returned to the abdominal cavity and the defect repaired, if this is possible without undue tension. If the tension is too great, then placing the bowel in a temporary prosthetic sac sutured to the abdominal wall allows the oedema to settle, and repair can be achieved once all the bowel has returned into the abdominal cavity, with daily tapering of the sac. Preformed silicone silos with a flexible ring base are now available and allow application in the newborn without the need for anaesthesia.

Persistent urachus or vitello-intestinal duct

Partial persistence of a urachus or vitello-intestinal duct is common, as an upward extension to the bladder or as a Meckel’s diverticulum. More complete failure of involution results in a fistulous communication and umbilical discharge of urine or gastrointestinal contents. Surgical excision of the fistula should be undertaken. A transverse incision lateral to the umbilicus provides good access for either condition. A urachus is traced to the bladder, divided and the bladder repaired. Co-existent bladder outlet obstruction should be excluded by a cystogram before surgery; the contrast is introduced into the bladder through a catheter inserted at the umbilicus. A vitello-intestinal duct is traced to the ileum and excised, with closure of the resultant opening into the bowel lumen.

Bladder exstrophy

Major failure of development of the lower abdominal wall results in a widely separated symphysis pubis, and the trigone of the bladder lies exposed on the surface with visible ureteric orifices. In male infants the penis is epispadic and even rudimentary. Reconstruction requires specialist surgery.

Congenital diaphragmatic hernia

A congenital diaphragmatic hernia is more common on the left, and much of the gut is often lying within the chest. Presentation is usually with respiratory distress and the diagnosis is confirmed by a chest X-ray. Although the surgery itself is straightforward, referral to a major paediatric centre is essential as, even after surgery, many babies still require intensive respiratory support. The presentation with respiratory distress is related more to the hypoplastic lungs associated with this condition than to the displaced bowel lying in the chest. It is for this reason that babies who present with respiratory difficulties at birth have a much worse prognosis than those in whom presentation is delayed until some hours later. Nasogastric aspiration is mandatory during transfer to a specialist centre, as a dilated stomach in the left chest further compromises gas exchange.

At surgery, which is performed via a transverse upper abdominal approach, the abdominal viscera are delivered from the thorax. The diaphragmatic defect is closed with interrupted non-absorbable sutures or, if the defect is too large, a mesh is used to bridge the defect.

Minor variants of the condition may present in late childhood and in adult life, and their management is discussed in Chapter 18.

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14

GENERAL TECHNIQUES IN ABDOMINAL AND GASTROINTESTINAL SURGERY

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PROBLEMS OF ACCESS

In many situations, an operation is technically demanding because of difficulties of access, and this is particularly so in intra-abdominal surgery. In some areas access is inherently difficult, whereas in others certain manoeuvres make the surgery immediately easier.

Abdominal wall access

The choice of abdominal incision or the position of laparoscopic ports is important. An inadequate incision is the commonest cause of operative difficulty (see Chapter 13). The abdominal muscles must be relaxed, both to reduce intra-abdominal pressure and to allow retraction of the abdominal wall. A self-retaining retractor is useful in major intra-abdominal surgery as it frees the assistant for the more precise and dynamic retraction in the area of dissection (Figure 14.1). A self-retaining retractor makes access more difficult to the lateral aspects of the anterior abdominal wall, and the release of any adhesions in this area should be completed before the retractor is positioned. Traditionally, the wound edges are protected from the retractor by large swabs but, more importantly, care must be taken not to catch a loop of small bowel. It is also easy to damage the abdominal or chest wall skin in the ratchet mechanism of a retractor.

Adhesions

Intraperitoneal adhesions may severely limit access within the abdomen. Thus, the release of these adhesions is often necessary before the planned surgery can proceed, and this may greatly increase the duration of an operation.[1] Adhesions are commonly the result of previous surgery, but they may also follow an intraperitoneal infective process or closed blunt trauma. Adhesions of small bowel to the anterior abdominal wall beneath an old scar are particularly dangerous, as it is easy to damage the bowel on the initial entry into the peritoneal cavity. Small bowel adhesions in the pelvis, to the site of previous surgery or pelvic infection, can also be difficult to release safely. Gentle traction will usually show the plane that requires division, either between the bowel loops or between bowel and the abdominal wall. Adhesions between loops of small bowel that are causing folds rather than kinks may be safely left undisturbed. Band adhesions, around which bowel loops could twist, should be divided even if division is not required for access.

Dissection

Much of the dissection within the abdomen consists of finding developmental areolar planes or the planes between adhesions. During dissection, the tissues must be held on stretch and the areolar tissue is divided as described in Chapter 1. Blunt dissection may result in tears in the bowel, liver or spleen, and should be avoided as much as possible. Blunt dissection is also more likely to tear fine structures such as autonomic nerves lying adjacent to the planes of dissection. Sharp dissection may be with scissors, scalpel or diathermy. Diathermy has the advantage of reducing minor bleeding, but also has a greater potential for damage, especially in the hands of the inexperienced, and may also cause thermal damage to a structure that initially displays no visible injury. It is therefore safer to use sharp dissection with scissors when dissecting close to bowel wall, a major vessel or a ureter.

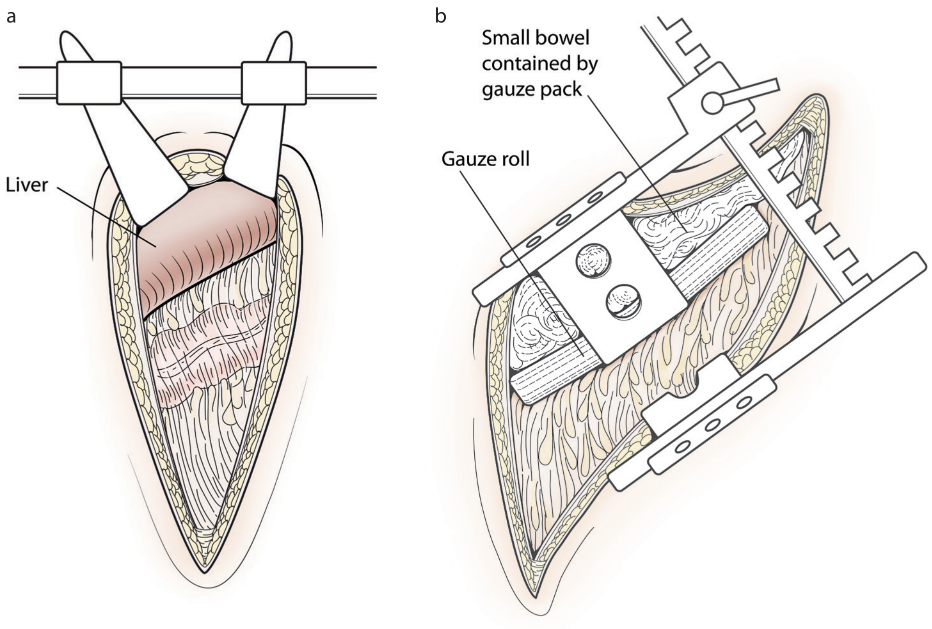

Figure 14.1 *(a) Mechanical fixed retraction to a horizontal bar attached to the operating table lifts the costal margin upwards and cranially, increasing subdiaphragmatic access. (b) The deep self-retaining 'Finochetti' retractor is holding the wound edges apart and is also holding the small bowel out of the pelvis. The small bowel has been wrapped in a large gauze pack, and a gauze roll has been placed along the left side of the mesenteric root.*

Laparoscopic dissection is performed by holding tissue on stretch and dividing areolar planes in a similar fashion to open surgery. A variety of blunt graspers have been designed for the retraction of tissue. A monopolar diathermy hook and scissors are the standard instruments for dissection. Alternatively, an ultrasonic dissector and coagulator can be used. Meticulous haemostasis is essential or visualisation rapidly deteriorates. Irrigation of the surgical field will clear small adherent blood clots, but irrigation fluid will then pool in dependent areas of the intraperitoneal space and can be challenging to aspirate.

If an injury to the bowel occurs during dissection, the segment should be examined carefully for any mucosal breach that will require repair. A seromuscular tear may be left unsutured but must be inspected carefully; however, it is often thought to be safer to support the thin intact mucosa with a partial-thickness seromuscular suture. If any repair is deemed advisable, it is better to do it immediately as it may be subsequently overlooked. Small bowel injury incurred at laparoscopy is easy to miss, as it may occur to a loop outwith the view of the laparoscope and the raised intra-abdominal pressure may limit or prevent contents from escaping into the peritoneal cavity.

Mobilisation of viscera

Even in the absence of adhesions, access to all intra-abdominal viscera is not secured immediately on entering the peritoneal cavity. For example, the stomach, although fully covered in peritoneum, has an inaccessible posterior wall until entry has been gained into the lesser sac. Posteriorly, fully and partially retroperitoneal structures lie in layers, and access to the more posterior structures must follow mobilisation of the more anterior ones. There are three retroperitoneal areolar planes in which the surgeon can dissect in order to achieve this mobilisation. The first plane is behind the colon and in front of the duodenum. The second plane is behind the duodenum, pancreas and spleen but in front of the kidneys, ureters and gonadal vessels. The third plane is behind the kidneys. The anatomy of the posterior abdominal planes and of the lesser sac, and the concept of discrete retroperitoneal mesenteries, can all be appreciated more readily from an embryological viewpoint.

Surgical embryology of the abdomen

Access within the abdomen is complicated by the intrauterine folding of the gastrointestinal tract, and therefore some understanding of abdominal embryology is essential for the surgeon.[2] In early intrauterine life the entire gastrointestinal tract is a simple tube that is suspended from a midline dorsal mesentery. The blood supply is from the three midline visceral arteries to the foregut, midgut and hindgut. These persist in adult life as the coeliac axis, the superior mesenteric artery and the inferior mesenteric artery, all arising in the midline from the front of the aorta.

The small bowel persists from early embryonic life into adult life on a mesentery orientated approximately in the midline. The large bowel, however, rotates in an anticlockwise direction, and the mesenteries of the ascending and descending colon then merge with the retroperitoneal tissue. The apposing two layers of peritoneum in contact are absorbed. It is relatively easy to appreciate this arrangement, as there is an areolar plane, which can be dissected with precision between the 'mesentery' of the ascending or descending colon and the truly retroperitoneal structures. If the ascending or descending colon is lifted forwards, a white line is visible on the peritoneum a few centimetres lateral to the colon. The areolar plane is entered by division of the peritoneum along this line, and the incision is continued around the colonic flexures. Access to the splenic flexure may be difficult, as it lies higher and deeper than the hepatic flexure and is attached to the diaphragm by a peritoneal fold, the phrenocolic ligament. Excessive traction must be avoided or adhesions between the colon and the lower pole of the spleen may be disrupted, with resultant splenic capsular tears. Once the areolar plane behind the colon has been entered, it can be followed to the midline and the colon is once again on its original midline mesentery. This is an important mobilisation manoeuvre and is the first step in an open radical hemicolectomy. It also allows operative access to the more posterior retroperitoneal structures. This first posterior plane is relatively easy to follow, and when difficulty is encountered the surgeon has usually strayed too far posteriorly. The second part of the duodenum and the pancreatic head are thus vulnerable to injury during a right colon mobilisation and, similarly, the duodenojejunal flexure and body of pancreas during a left colon mobilisation (Figure 14.2).

In the *pelvis*, a similar merging of tissue occurs between the mesorectum and the tissue of the pelvic wall. Again, there is a discrete plane of areolar tissue between the structures of the hindgut and the other structures in the pelvis. Fusion of the peritoneum in the depths of the rectovaginal or rectovesical pouch forms Denonvillier's fascia, which is an important anatomical landmark in radical surgery of the rectum.

In the *upper abdomen* the developmental rotation of the foregut is more complicated (Figure 14.3). Subsequent fusion of folds also complicates the anatomy around the transverse colon. The stomach originates as a dilatation of the foregut, with a dorsal and ventral mesentery. The dorsal aspect of the stomach grows more rapidly than the ventral aspect, forcing

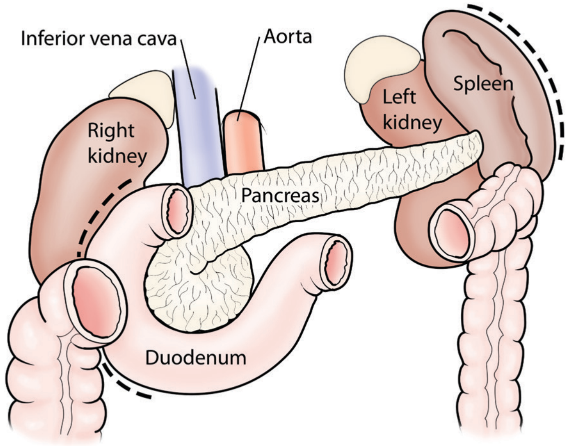

Figure 14.2 *The embryological folding of the gut produces layers of mainly retroperitoneal organs, which can be separated along areolar planes. The anterior layer consists of colon. The middle layer, of pancreas, duodenum and spleen, can be mobilised forwards by peritoneal incisions in the positions marked by the dotted lines. The posterior layer is made up of the kidneys, adrenals, aorta and vena cava.*

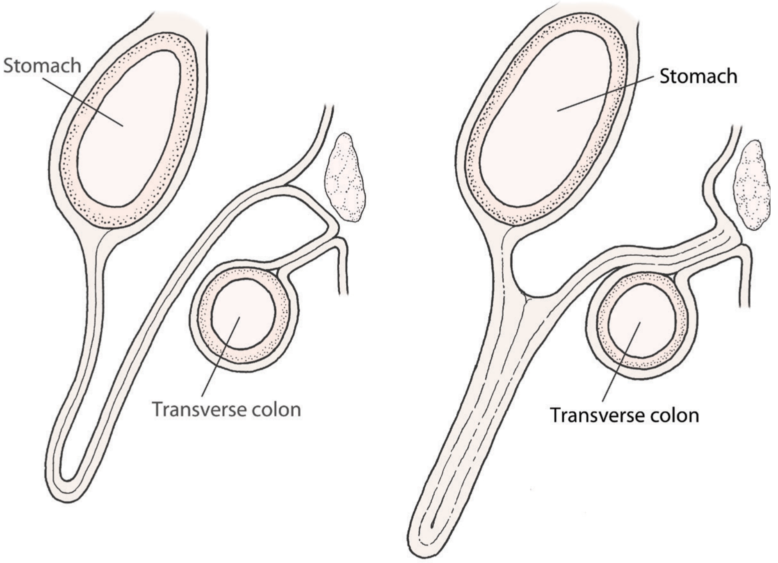

Figure 14.3 *The developmental rotation and differential growth of the gut results in complicated upper abdominal anatomy. The greater omentum with the transverse colon effectively divides the abdomen into a supracolic and an infracolic compartment.*

the distal stomach and duodenum upwards and to the right. The ventral mesentery becomes the lesser omentum and the dorsal mesentery the greater omentum. The duodenum also rotates to the right, and its right side loses its peritoneal covering as it fuses with the retroperitoneal tissue. There is a plane here that can be developed in the manoeuvre entitled '*Kocherisation of the duodenum*'. An incision of the peritoneum outside the lateral border of the second part of the duodenum allows the duodenum and the head of the pancreas to be lifted forwards off the right kidney and inferior vena cava (IVC). The equivalent plane on the left is behind the spleen and tail of the pancreas. It is entered by division of the peritoneum lateral to the spleen (see Figure 14.2); this is the second posterior plane.

The adult anatomy of the upper gastrointestinal tract is shown in Figure 14.4. The *lesser sac* forms behind the stomach as it rotates, the anterior wall of the sac being composed mainly of the posterior wall (the original right wall) of the stomach. It is in communication with the rest of the peritoneal cavity – the *greater sac* – but, due to differential growth, only by the small communication deep to the free edge of the lesser omentum. Lesser sac access is necessary for many upper gastrointestinal and hepatobiliary operations. The natural communication between the greater and lesser sacs cannot be enlarged as the common bile duct, portal vein and hepatic artery run in the free edge of the lesser omentum, and the other boundaries of the channel are the IVC, the duodenum and the liver. The lesser sac may be entered through the lesser omentum away from the structures in the free edge, but access is limited. Entry below the greater curve of the stomach, through the gastrocolic part of the greater omentum, is satisfactory, but multiple ligations of gastric or omental branches of the gastroepiploic arcade are required and devitalisation of the omentum may occur. Access through the transverse mesocolon risks injury to middle colic vessels, although a relatively avascular window to the left of these vessels can be utilised. The most extensive access can be obtained by separating the natural plane between the greater omentum and the anterior surface of the transverse colon. Once the plane has been identified it can be followed to right and left for a considerable distance, providing extensive access to the lesser sac. Only occasional small vessels cross the plane and require ligation. This plane is continuous around the colonic flexures with the plane that is developed to mobilise the ascending and descending colon.

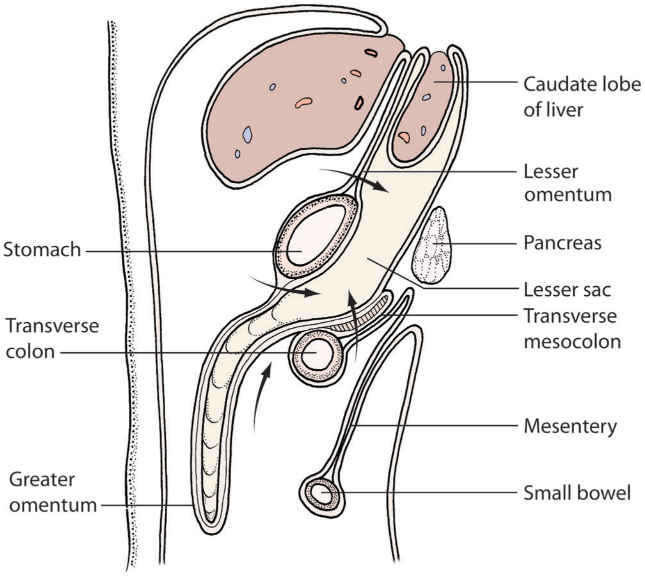

Figure 14.4 *A diagrammatic sagittal section through the abdomen to show the disposition of the omentum and lesser sac. Arrows indicate routes of access into the lesser sac.*

Access to major vessels for vascular control is more fully addressed in Chapter 6. In general, however, the infrarenal aorta may be approached by swinging the transverse colon up and the small bowel to the patient's right. The posterior peritoneum is opened to the left of the fourth part of the duodenum. The IVC is exposed by Kocherisation of the duodenum, but access to the intrahepatic IVC requires full mobilisation of the right half of the liver. The third posterior plane behind the kidneys may be valuable for access to the posterior aspect of the intra-abdominal aorta or IVC.

Retraction of intra-abdominal viscera

Mobile bowel and other intra-abdominal viscera have to be held out of the operative field. Distended obstructed bowel may impede access for safe dissection and deflation may be necessary early in a laparotomy, although, when a resection is planned, it can often be deferred and undertaken when the bowel is opened at the time of the resection.

DEFLATION OF BOWEL

Gastric deflation can be achieved using nasogastric tube aspiration and jejunal contents can be 'milked' back into the stomach, from where they can also be aspirated (see Figure 23.3, p. 414). Small bowel can also be deflated by the introduction of a needle, attached to suction, obliquely through the wall of the distended bowel. This technique, while excellent for gas or thin fluids, is unsuitable for thicker contents. Alternatively, the whole sucker is introduced through a small enterotomy into the bowel lumen. Before making the incision, a purse-string suture should be placed, which can be tightened immediately on introduction of the sucker to prevent leakage. After removal of the sucker the suture is tightened and tied to close the enterotomy. This is a safer technique in the small bowel than in the colon. An obstructed distended colon has solid matter, which blocks suction tubing, and the only satisfactory solution may be *on-table lavage*, which is described in Chapter 23.

Fixed and hand-held retractors are the main methods by which the operative field is displayed in open surgery. Gravity can also be utilised to increase potential spaces, for example between the diaphragm and liver. Mobile bowel can be delivered outside the abdomen and placed in a bowel bag, which prevents fluid loss from the surface. Cooling, however, is still inevitable and postoperative ileus may be less of a problem if the bowel can be 'packed away' within the abdomen. For example, if a left hemicolectomy is planned, the small bowel is delivered externally over the right abdominal wall. A large pack soaked in saline is then tucked into the mesenteric root from the left and the small bowel swung back on top of it. The remainder of the pack is then folded over the small bowel and used to retain it under the right side of the abdominal incision (Figure 14.5). A 20-cm (8-inch) gauze roll can then be placed to the left of the wrapped bowel along the mesenteric root, and a deep self-retaining wound retractor opened so that the blade on the right wound edge pushes on the roll and the small bowel is held securely within the right half of the abdomen (see Figure 14.1b).

In laparoscopic surgery the assistant usually has only one instrument available with which to retract and much greater use is made of gravity to assist. Additional retraction may be provided by fixed retractors inserted through the abdominal wall, often used to retract the liver in upper abdominal surgery. Alternatively, a suture with a straight needle can be passed through the abdominal wall from outside and through a structure such as the uterus before being passed back through the abdominal wall, where it can be used to retract the uterus during pelvic surgery.

Removal of debris and blood, fluid and smoke of diathermy

These must be removed from the operative field so that a clear view is maintained. Mechanical suction is satisfactory except when there is solid matter. The suction end may have a single terminal opening, allowing accurate clearance of a defined area. A clear view of the sucker tip is essential because if the single suction hole is occluded against tissue, damage can occur as the tissue is sucked into the device. Alternatively, a guard with multiple holes is screwed over the sucker. This is a safer instrument because if one hole is occluded against the bowel wall, the remaining open channels continue to draw in fluid or air. This prevents the suction from drawing in tissue. It is therefore safe to pass a guarded sucker amongst small bowel loops to aspirate fluid or blood. Gentleness is still essential to avoid injury, but the surgeon does not need to be able to see the end of the instrument.

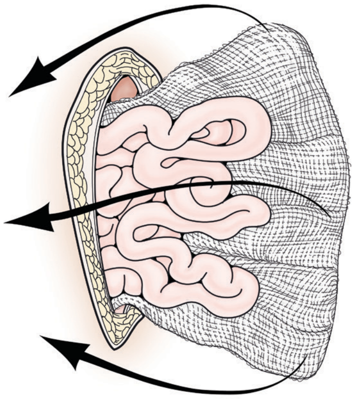

Figure 14.5 *A large pack is tucked into the left side of the mesenteric root. It is folded over the small bowel, which can then be retained in the right half of the abdomen by the method shown in Figure 14.1b.*

Blood clots and solid faecal material will block a sucker, and it is preferable to remove them with a swab.

SWAB COUNT

In intra-abdominal surgery it is easy to leave a swab undetected within the peritoneal cavity. It is therefore essential to check the number of swabs and instruments, and to account for all, before closing the peritoneum. As all swabs used in surgery should have a radiopaque marker, if a swab is unaccounted for at the end of an operation, an abdominal X-ray should be performed to locate the retained swab.

INTRA-ABDOMINAL OPERATIVE ASSESSMENT

When the peritoneal cavity is entered there is an opportunity not only to assess the pathology for which the operation is intended, but also to check for any other as yet undiagnosed condition. For example, peritoneal malignant deposits, although easily visualised or palpated at surgery, are often undetected by sophisticated preoperative imaging. Even with a limited-access abdominal incision for the removal of an appendix, it is usually possible to check at least the terminal ileum and the right ovary, which is particularly important if the appendix has proved to be normal. A major abdominal incision allows a fuller assessment, as does a laparoscopy. It is a good discipline to do this immediately on opening the abdomen or it may be forgotten later. Mobilisation of organs or entry into the lesser sac is only required if there is a specific concern that justifies it. At open surgery the small bowel can be followed throughout its length, the omentum lifted and the large bowel palpated as far as the mid rectum. Views may be restricted, but the pelvic organs, the stomach, liver and gallbladder can also all be palpated, as can the retroperitoneal organs. At laparoscopy, although visualisation is usually superior, direct palpation is impossible, although instruments allow limited palpation by experienced surgeons.

GASTROSTOMIES, ENTEROSTOMIES AND COLOSTOMIES

Gastrotomy, enterotomy or colotomy merely indicates a simple incision into the lumen of the gastrointestinal tract. These incisions are closed with a similar technique to a sutured anastomosis, which is described below. Gastrostomy, enterostomy and colostomy indicate the establishment of a connection from the lumen of the gastrointestinal tract to the abdominal wall skin. Those in which a mucocutaneous anastomosis, or stoma, is formed are described in Chapter 22. A connection can also be established by a tube secured into the lumen.

TUBE GASTROSTOMY

A tube gastrostomy may be fashioned when the abdomen is already open. A balloon catheter is introduced through the anterior abdominal wall in a position where the stomach can be apposed to the abdominal wall without tension. A small incision is then made in the anterior stomach wall inside a purse-string suture, the catheter is introduced and the suture snugged around the catheter. The anterior wall of the stomach should then be fixed to the anterior abdominal wall to prevent dragging, to eliminate a length of intraperitoneal catheter around which bowel could twist, and to minimise the consequences of any minor leakage. Currently, the commonest gastrostomy is achieved by a non-operative percutaneous endoscopic gastrostomy (PEG) method (see Chapter 12).

FINE-BORE TUBE ENTEROSTOMY

Fine-bore tube enterostomy can be used for enteral feeding; the technique for this is described in Chapter 12.

TUBE CAECOSTOMY

Tube caecostomy is established by a similar technique to that used for an open gastroscopy. Its place is limited but tube caecostomy is discussed in more detail in Chapter 23.

ANASTOMOTIC TECHNIQUE

The basic principles of this procedure are similar whether the surgery is to close a simple incision into the gastrointestinal lumen or to create an anastomosis. A simple opening into a lumen may be made to retrieve a gallstone from the common bile duct or a foreign body from the stomach that cannot be retrieved endoscopically. The duodenum may have been opened to gain access to the ampulla or to oversew a bleeding ulcer. An incision may have been made accidentally into the small bowel during the dissection of adhesions. A clean incision is simply sutured, as in the construction of an anastomosis. However, care must be taken not to narrow a small diameter lumen, and it is therefore sometimes appropriate to close a short longitudinal incision transversely provided that this does not put tension on the closure. More often, a lumen is opened prior to a resection or bypass, and the anastomosis is then performed to restore gastrointestinal continuity.

An anastomosis may be either end-to-end (Figure 14.7), end-to-side (see Figure 22.15, p. 391) or side-to-side (see Figure 14.11). It may be created between two segments of bowel or between small bowel and another viscus such as the stomach, pancreas or bile duct. The anastomosis may even be between an isolated loop of small bowel and the bladder. Individual circumstances and techniques are described in the relevant sections, but the principles are universal, whether the anastomosis is hand-sutured or stapled and whether it is performed at laparotomy or laparoscopy. In laparoscopic resections, bowel ends can, on occasion, be conveniently brought outside the body, for example when a right hemicolectomy specimen is delivered through a small incision. The anastomosis can then be performed extracorporeally. When an anastomosis must be performed within the abdomen, hand-sewn methods are generally avoided, as suture manipulation is both time-consuming and technically demanding, and mechanical stapling devices are used routinely.

BLOOD SUPPLY

For sound healing a good blood supply to both sides of an anastomosis is crucial. It may be possible to see the vessels in the mesentery or, in an obese patient, to feel for their pulsation in order to choose a site for resection where the blood supply of the divided bowel will be optimal. The viability of the ends must be confirmed before commencing the anastomosis. The mucosa should be pink and the bleeding from cut submucosal vessels should be bright red. (This sign is lost if the bowel is divided by diathermy.) If an artery close to the bowel wall at the level of the anastomosis is divided before ligation, pulsatile arterial bleeding from the cut end is an extra reassurance. In general, the blood supply to the colon is more precarious than that to the small bowel and stomach. A dusky grey-pink mucosa and bleeding that is the dark ooze of venous back-bleeding are indications that the circulation is inadequate for an anastomosis. The ends must then be resected back to healthy, well-perfused tissue. In a side-to-side anastomotic bypass, blood supply is unlikely to be of concern.

TENSION

The two sides of the anastomosis must lie easily together without tension, which increases the danger of disruption. The surgeon must take into account the likely postoperative increase in tension secondary to inflammatory swelling and ileus. Changes in body position and the filling of the stomach or bladder will also change the alignment and the tension of an anastomosis to these organs. Where there is concern, further mobilisation of the ends, without causing damage to the blood supply, is required. If this cannot be achieved, a more sophisticated method of restoring continuity is required.

ANASTOMOTIC DIAMETER

An end-to-end anastomosis inevitably reduces the lumen at the site of the anastomosis, whether hand-sutured or stapled. Temporarily, the lumen is further narrowed by postoperative oedema, and if it becomes obstructed, the risk of anastomotic breakdown is increased. This problem is greater if the lumen is of small diameter or the luminal contents are viscous. The traditional sutured two-layer anastomotic technique – which is now seldom used for intestinal end-to-end anastomoses – narrowed an anastomosis significantly as the suture line was invaginated (Figure 14.8). Paediatric surgeons changed to a single-layer technique before general surgeons, as the narrowing was more critical in the narrow lumen of the neonatal bowel. A side-to-side anastomosis can be fashioned with whatever anastomotic diameter the surgeon chooses. A hand-sewn, end-to-end anastomosis may be enlarged by an oblique division of the ends, or an enlargement can be created by cutting back on the anti-mesenteric border. This is also a useful manoeuvre if the diameters of the two ends are significantly disparate (see Figure 14.6). Temporary intubation of an anastomosis may be protective and is sometimes used for the biliary tract, the pancreatic ducts and the ureter.

MESENTERY

On completion of an anastomosis there is usually a mesenteric defect, which is a potential site for an 'internal hernia'. Small bowel may pass through this defect, with resultant volvulus or strangulation, and most surgeons believe that these defects should be closed (see Figure 14.6). The suture material and method of closure are not important, but care must be taken to avoid injury to mesenteric vessels. A stitch that only picks up the peritoneum of the mesentery is safest.

DRAINS

A surgeon may be concerned about an anastomosis because of a marginally adequate blood supply or minimal tension. There may have been peritonitis at the time of surgery or the patient's general condition may be poor. The surgeon may then consider 'protecting' the vulnerable anastomosis with a drain. However, sutures or staples can hold non-viable tissue in position and delay a leak for 1–2 weeks. The drain would have to remain *in situ* for 2 weeks to be of any value in this situation, and there is some concern that a drain in contact with an anastomosis for this length of time could in itself cause damage. However, pancreatic anastomoses are particularly prone to delayed leaks and, therefore, are commonly drained and the drain left *in situ* until this period of danger is passed.

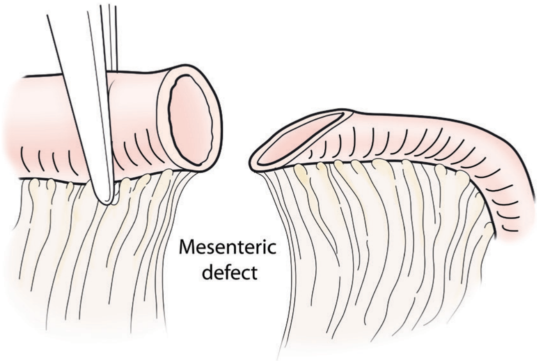

Figure. 14.6 *The anastomotic diameter can be increased by oblique division of the bowel. The mesenteric border should be longer than the antimesenteric border to ensure good blood supply. A longitudinal incision or 'cut-back' at the antimesenteric border produces the same effect. A soft occlusion clamp has been used to prevent spillage of intestinal contents. After completion of the anastomosis the mesenteric defect should be closed.*

There are, though, some instances where a short-term drain may be of value. For example, many sound urological anastomoses leak a considerable volume of urine during the first 72 hours but then seal and heal satisfactorily, and in biliary surgery a significant bile leak may be identified early if a drain is *in situ*. An infected haematoma that has collected in the 'dead space' of the emptied pelvis after a low anterior resection is believed to be one of the causes of anastomotic breakdown when it later discharges through the anastomosis. A short-term pelvic suction drain is therefore often employed to prevent this collection and to protect the anastomosis.

Low-pressure suction is preferable to high-pressure suction, which may draw tissue into the drain and cause damage. In addition, low-pressure suction is often more effective as the drain holes are less likely to be occluded by tissue drawn into them.

Sutured end-to-end anastomosis

This versatile anastomosis is illustrated for the colon (see Figure 14.7). However, a sutured end-to-end small bowel anastomosis is often the first that a trainee surgeon performs. Mobility makes the surgery technically easy, the blood supply is good and breakdown uncommon. As discussed already, the two ends must have a good blood supply and be able to be brought together easily without tension. Discrepancies in diameter between the ends can be adjusted by the spacing of sutures, as the bowel wall is elastic. Alternatively, the smaller-lumened tube can be cut at the antimesenteric border to equalise the diameter (see Figure 14.6). Care should be taken over orientation, because if there is ample mobility, then one end can be inadvertently rotated. The anastomosis should be undertaken without fear of spillage of contents during the procedure, and non-crushing occlusion clamps may be necessary. They are placed proximally and distally to isolate the area of bowel to be opened from ongoing inflow of gastrointestinal contents until the anastomosis is complete (see Figure 14.6). However, this has the disadvantage of compromising the blood supply, which may be critical to the healing of the anastomosis. Alternatively, a sucker with guard can be introduced into the divided bowel ends and guided up the lumen to clear contents.

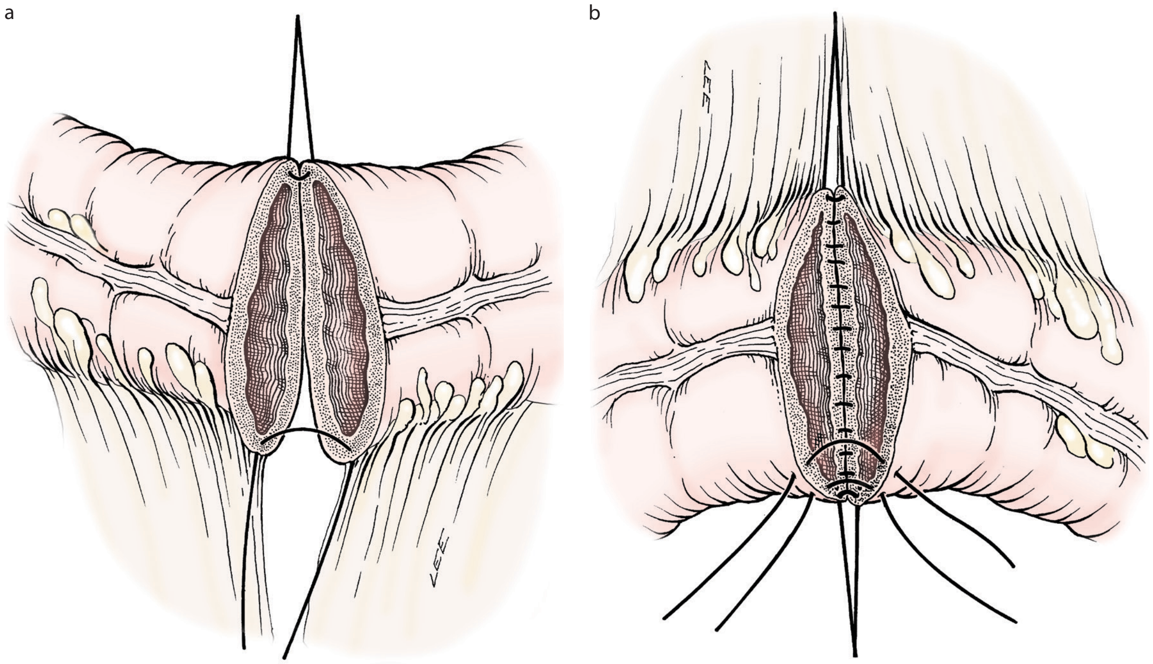

Figure 14.7 *An end-to-end bowel anastomosis with a single layer of interrupted extramucosal sutures. (a) The first two sutures are placed at the mesenteric and antimesenteric borders, and used as stay sutures. (b) Half of the anastomosis is completed and the bowel has been turned over to suture the second half.*

Minor bleeding points in the submucosa can be ignored. Precise coagulation diathermy will arrest the more troublesome bleeding points, but many surgeons prefer to divide the bowel with diathermy to reduce bleeding.

SUTURE MATERIAL

The choice of suture material is often dependent only on the preference of the surgeon; for example, knots may feel more secure with a braided material but a slippery monofilament material slides better if a parachuting technique is needed. Additionally, the choice between an absorbable and a non-absorbable suture is again often one of personal preference. However, non-absorbable sutures should be avoided in biliary and urinary anastomoses, where sutures – in particular braided material such as silk – have been found as the nidus within a subsequent calculus.

TECHNIQUE

A single layer of interrupted extramucosal sutures is now favoured by the majority of surgeons. A continuous suture acts like a drawstring and will tend to narrow the lumen, especially in the early phase when postoperative swelling further tightens the suture. In addition, a continuous suture reduces the blood supply to the cut ends; this is disadvantageous except in very vascular areas where a haemostatic suture may be beneficial. Sutures that include the mucosa have no advantage other than haemostasis. They do not add significantly to the strength of the anastomosis nor do they improve apposition, as the mucosa already lies in apposition after accurately placed extramucosal sutures. Mucosa heals rapidly, and a watertight seal will have formed within 24 hours. Sutures that include the mucosa merely delay this by the trauma and ischaemia that they cause, and in experimental models, a small mucosal ulcer can be seen at each suture site.

Historically, when two layers of sutures were used routinely, it was believed that the second seromuscular layer was important to invaginate and bury the mucosa of the cut ends (see Figure 14.8). This does not confer any benefit and causes narrowing and greater tissue strangulation.

The first two sutures are placed to unite the two ends at the mesenteric and antimesenteric borders, and they divide the anastomosis into two equal sections. These sutures are tied, the ends left long and held in artery forceps (Figure 14.7a). Each suture should start on the outside and emerge between the mucosa and the muscularis mucosa. It is important to include the muscularis mucosa, which is visible as a white line, as it has significant strength. These layers are distinct and mobile on each other if the bowel has been cut with scissors or a scalpel. Diathermy division of the bowel to some extent 'fuses' the layers, and the anatomy of the layers may be less distinct. The ideal size of the suture bite may be difficult to judge. A larger bite has less danger of cutting out, but it creates a larger bulk of potentially strangulated tissue to narrow the lumen. In the adult small bowel a reasonable compromise is to introduce the suture 0.5 cm from the cut end. The suture is then introduced into the other cut bowel end between the muscularis mucosa and the mucosa and brought out through the peritoneal surface

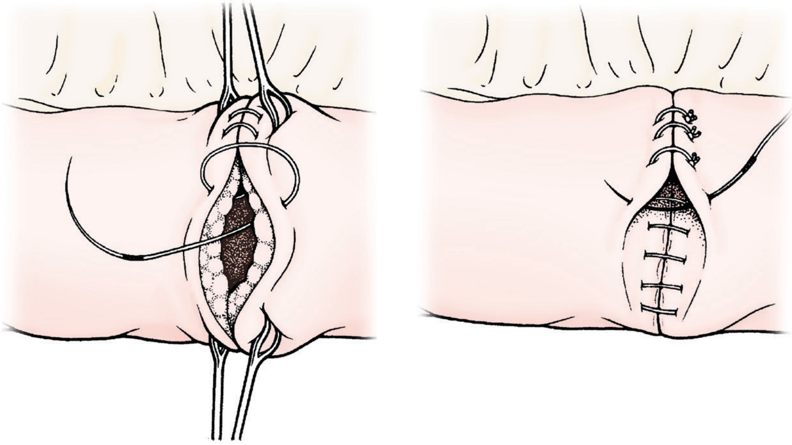

Figure 14.8 *The classic two-layer anastomosis is now seldom employed for an end-to-end anastomosis.*

(0.5 cm from the cut end). Care must be taken as the throws on the knot are tightened to prevent the whole suture tightening and strangulating the tissue. The spacing of sutures is difficult to judge, and the temptation to place them very close, in anticipation of the dilatation of postoperative ileus, should be resisted. The additional compromise to the blood supply outweighs any benefits of an apparently more watertight early closure. In an adult small bowel, sutures at intervals of 0.5 cm are a satisfactory compromise. Subsequent sutures are placed until half of the anastomosis is complete. The bowel is then turned over and the other half of the anastomosis completed (Figure 14.7b).

In most other situations access is less ideal, and it is important to complete the back wall of the anastomosis first. A similar technique to that described above can be employed if the surgeon starts at the back corner, which is furthest away, and this first suture is left long as a stay suture. This suture makes the placement of the next suture easier, and it is possible to continue along the back wall of the anastomosis until the back corner nearest the surgeon is reached. This last suture is also left long as a stay suture (Figure 14.9a). The front wall is then anastomosed. Another alternative is to introduce the sutures along the back wall of the anastomosis from within the bowel lumen (Figure 14.9b). These sutures have knots in the submucosal plane, which in theory is less than ideal but in practice is satisfactory. In a difficult anastomosis, where access is very restricted, sutures may be *parachuted* or *railroaded* into position. The two ends are only apposed after all sutures are in place (Figure 14.10). Many of these problems, which are encountered particularly in oesophageal and rectal anastomoses, can be overcome by use of a circular stapling device.

In some structures, such as the common bile duct, a separate mobile mucosa may not be apparent. The interrupted sutures should then be placed full thickness if it is not practical to exclude the mucosa.

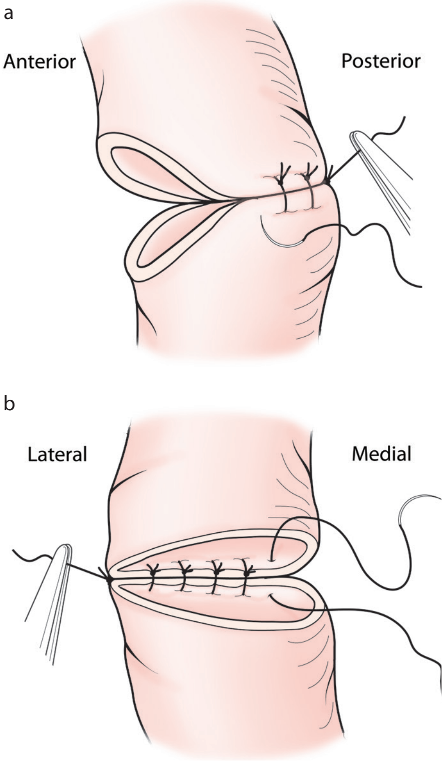

Figure 14.9 *(a) The back wall of a colorectal anastomosis sutured from behind. All knots are on the serosal surface. (b) An alternative is to place the back wall sutures from within the lumen. The knots will lie in the submucosal plane.*

An *end-to-side sutured anastomosis* is merely an adaptation of the end-to-end technique. An incision is made in the side of the viscus to which the end is to be joined. The length of the incision should be such that there are two equal ‘lumens’ for the anastomosis. The suture technique used is similar to that described for an end-to-end anastomosis.

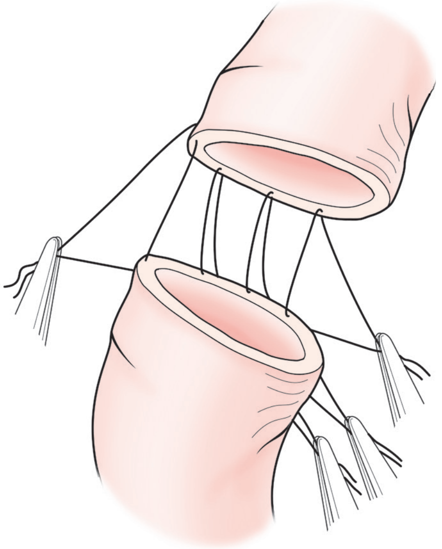

Figure 14.10 *The sutures are all in place before the two ends are apposed. This 'railroad' technique is useful where access is very restricted.*

Sutured side-to-side anastomosis

This is a useful anastomosis when a segment of gastrointestinal tract is to be left *in situ* but bypassed. It may be undertaken in a similar fashion to the end-to-side anastomosis described above and constructed with a single layer of interrupted sutures. If, however, both sides of the anastomosis have a rich blood supply, making haemostasis of the cut ends important, a continuous suture technique has advantages. A second suture layer also adds stability to the anastomosis and there need be no concern in a wide side-to-side anastomosis that a two-layer continuous technique will significantly narrow the anastomotic diameter. Side-to-side anastomosis is a method commonly employed in anastomoses between the stomach and small bowel. The traditional, hand-sewn technique for gastroenterostomy or enteroenterostomy is described below.

Most surgeons use clamps for this operation in order to steady the gut, control haemorrhage and prevent the escape of contents, but others prefer to rely on a skilled assistant. The clamps must be of the light *occlusion* type, which will cause minimum trauma to the segment of each viscus included in the clamp. An 8- or 9-cm portion should be held within the clamp for a gastroenterostomy, but for an enteroenterostomy about half of this length will suffice. A swab is laid underneath to absorb any spillage and the two clamps are approximated. They are secured with a locking device or are tied together (Figure 14.11). The outer suture is a continuous seromuscular suture, and the inner suture is an 'all-layer' continuous suture. This is achieved by four separate suturing manoeuvres.

Posterior seromuscular suture. This is a continuous absorbable suture that does not include the mucosa and that unites the adjacent surfaces of gut. A short end is retained in forceps at the start of this layer and, at completion, the suture is retained for later use as the anterior seromuscular suture. The suture is tied to the loop of the last stitch at the end of the posterior seromuscular layer. This locks the continuous suture and also provides a loop of suture material that can be held in artery forceps as a stay suture to steady the anastomosis when the clamps are removed. The lumen of each segment is now opened, within the limits of the posterior seromuscular suture, by an incision parallel to the suture line and approximately 5 mm from it (Figure 14.11a). The incision for a gastroenterostomy will therefore be about 5–6 cm. In the first instance, the incision should be made through the serosal and muscular coats only; the mucosa is then picked up with forceps and incised separately. If diathermy is used for the incision, care must be taken to avoid injury to the opposite mucosal layer. On occasions when no clamps are employed, a sucker should be introduced through the initial mucosal incision to remove contents and prevent spillage.

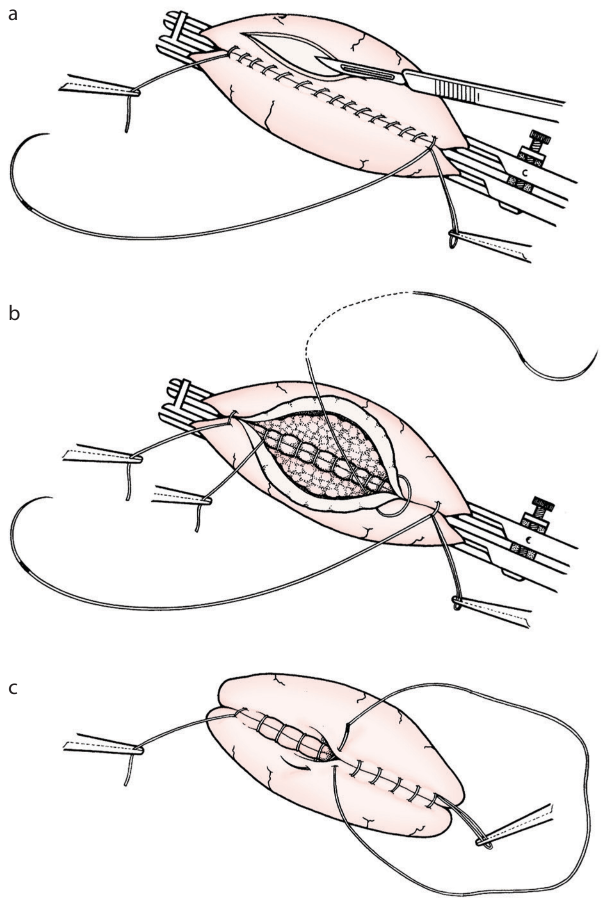

Figure 14.11 *A side-to-side anastomosis utilising twin occlusion clamps. (a) The posterior seromuscular suture is completed and the lumen is opened. (b) The posterior all-layer suture is completed and the anterior all-layer suture is in progress. (c) The final anterior seromuscular suture is nearing completion.*

Posterior all-layer suture. This suture begins at one extremity of the incisions and unites the posterior cut edges, traversing all coats of the gut. The first stitch should enter the lumen lateral to the end of one incision and, after ligation, the end of the suture is held in forceps (Figure 14.12). An ordinary

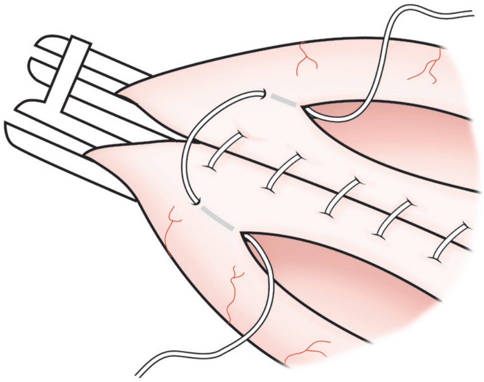

Figure 14.12 *The first suture should enter the lumen lateral to the end of the enterotomy incision. At the other end, care must again be taken to place the suture beyond the extremity of the incision.*

over-and-over continuous suture is employed but, after every five or six stitches, a lock-stitch may be inserted to prevent a possible purse-string effect as the suture is tightened. When the other extremity of the incisions is reached, the suture is carried round the corner and continued in the reverse direction as the anterior all-layer suture. Particular care must be taken when turning the corner to ensure that an all-layer suture is again placed beyond the extremity of the incision.

Anterior all-layer suture. This suture begins as a continuation of the posterior layer, the needle passing from one lumen to the other as before, except that the wall of each gut edge must be traversed separately (see Figure 14.11b). As the suture is tightened, the mucosa is inverted by the loop of thread that has been inserted. Any tendency to eversion can be overcome by the assistant gently pressing on the cut edges with forceps as the suture is tightened. The suture is continued in this manner to complete the join of the cut edges of gut. The suture is tied to the original end that was held in forceps at the start of the posterior all-layer suture. The anastomosis should now be watertight and the clamps are removed.

Anterior seromuscular suture. This suture begins as a continuation of the posterior seromuscular suture and on completion is tied to the end that was held in forceps at the start of the procedure (see Figure 14.11c).

Numerous minor modifications of the traditional, hand-sewn technique for gastroenterostomy or enteroenterostomy are in common use.

MECHANICAL STAPLING DEVICES WITHIN THE ABDOMEN

Mechanical stapling devices have progressively replaced the traditional sutured techniques. In many situations in open surgery the main advantage is speed, while the disadvantage is cost. However, a hand-sewn anastomosis can be very difficult when access is severely limited, and it is in these circumstances that mechanical stapling devices have major advantages. One or more rows or circles of staples hold the tissue in apposition. When the device is employed from outside the bowel lumen, the mucosa is held in apposition and an eversion closure of the bowel wall is produced (Figure 14.13). When the device is employed from within the lumen, the serosa is held in apposition with an inversion anastomosis (Figures 14.14 and 14.15). Initial theoretical concerns that healing would be poor when either intact mucosa or intact

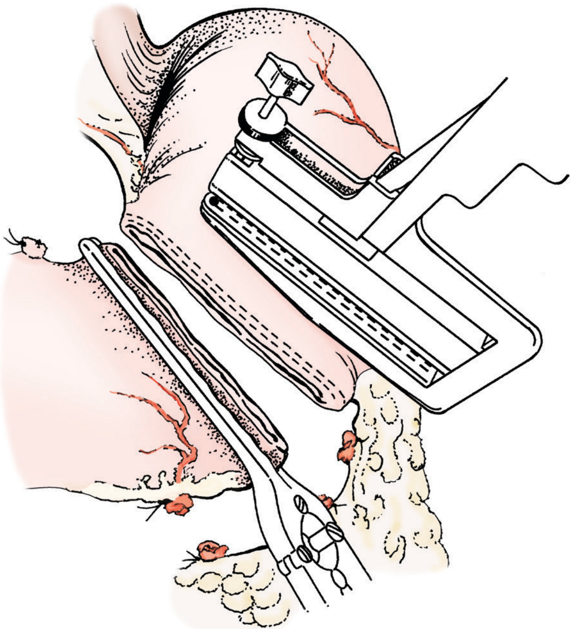

Figure 14.13 *A crushing clamp temporarily seals the distal stomach, which will be removed in this partial gastrectomy. The proximal stomach has been sealed with a double row of staples delivered from a linear stapling device. The stomach has been divided between the two sealed lines.*

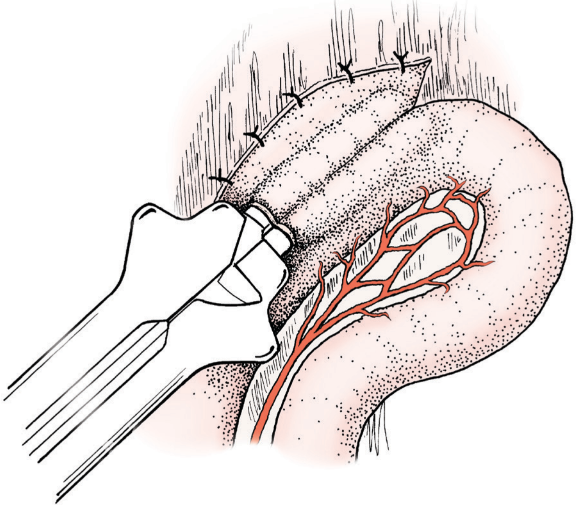

Figure 14.14 *A linear cutting stapling device, with one blade in the stomach and one in the jejunum, can be used to create a stapled gastroenterostomy. The two small incisions for the insertion of the blades must then be closed.*

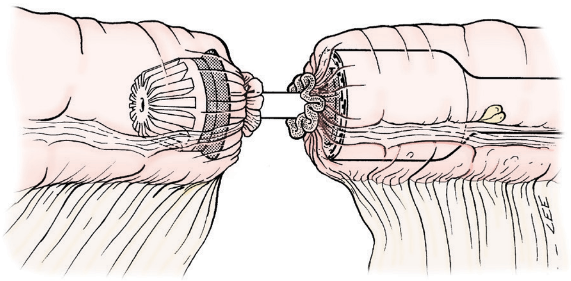

Figure 14.15 *An anastomosis with a circular stapling device. The head and anvil of the device are inserted separately into the two segments of bowel to be anastomosed. The two parts of the device are then locked together and the bowel is approximated over the area through which the staples are to be fired. When the staples are fired, a circular blade amputates the tissue lying within the lumen and this consists of a 'doughnut' of proximal and of distal bowel.*

serosa was apposed have proved to be unfounded. An additional theoretical objection to an everted stapled anastomosis is that it leaves mucosa exposed to the peritoneal cavity. This was against all the early surgical principles of anastomotic technique. In general, little difference has been found in numerous studies comparing outcome in stapled versus hand-sewn anastomoses. Stapling devices can be divided broadly into linear and circular instruments and into those that incorporate a cutting action and those that do not.

Linear staplers

Linear staplers deliver several rows of parallel staples and may, in addition, have a cutting mechanism between the rows of staples. The staple line is commonly either in line with, or at right angles to, the handle of the instrument, but other angulations are also available. Preference for each type is dependent on the challenges of access (see Figures 14.13 and 14.14).

LINEAR STAPLERS WITHOUT A CUTTING BLADE

When fired from outside the bowel, two parallel rows of staples appose the mucosa and close the lumen, but the tissue is not divided (Figure 14.13). These staplers can be used, for example, to reduce the size of the available stomach in a gastropexy for morbid obesity and to close the rectum below a tumour during an anterior resection. A linear stapler, fired with one blade inserted into an intermittently retracting ileostomy, will hold the serosal surfaces of the spout apposed and may prevent retraction. A simple linear stapler can easily be mistaken for one that also cuts between the staple line, and care must be taken to select the appropriate instrument.

LINEAR STAPLES WITH A CUTTING BLADE

These extremely useful instruments deliver four rows of parallel staples and cut between the middle two staple lines. They may be used for dividing bowel and sealing both ends. They are particularly useful when one end is to be brought out as a terminal stoma, as abdominal wall contamination is minimised and the bulk of a clamp is avoided. The distal divided end is also already closed and can simply be dropped back into the peritoneal cavity. The duodenal division in a gastrectomy is another application of this technique. Many surgeons opt for an additional seromuscular suture both to bury the exposed mucosa and to provide additional security to the closure of a stapled stump left *in situ*. Initially, this was standard practice in many situations to reduce the risk of staple line leaks and haemorrhage, but the necessity for this suture is increasingly questioned.[3] Staple line reinforcement can also be achieved by specifically designed bioabsorbable material that is either applied exogenously or incorporated into the staple line. Stapling devises that have this material as an integral feature are advocated by some surgeons.[4]

If the two blades of the stapler are placed in different segments of gut, firing the device creates an anastomosis (Figure 14.14). There is, however, still the necessity to close the defects through which the blades have been introduced. These stapling devices are used extensively in gastric anastomoses and for creating ileal and colonic pouches. Further details of their use in these situations are described in the relevant sections.

Small linear stapling devices with a cutting blade can secure and divide a blood vessel, and these have a particular role in laparoscopic surgery. Ligation or transfixion ligation is suitable for most vessels that have to be divided at open surgery. Some short, wide vessels cannot be secured in this fashion, and a sutured closure of the short stump of such a vessel is technically demanding if access is restricted. These small linear stapling devices have thus proved extremely useful in this situation and are used, for example, for the division of the hepatic veins in hepatectomy.

Circular stapling devices

Circular staplers are the instruments that have revolutionised the challenges posed by low rectal and oesophageal anastomoses. The instrument can be separated into two portions, which are later locked together. In a classical end-to-end low colorectal anastomosis, the smaller portion (or head) of the instrument is inserted through the cut end of the mobilised descending colon, which is drawn over the instrument with a purse-string suture so that only the locking mechanism protrudes. The main body of the instrument is then introduced through the anus. The distal bowel wall must also be drawn securely over the portion of the device from which the staples are fired. If the rectal stump has been closed by staples, the spike of the shaft of the gun has simply to pierce the closed stump. Alternatively, a purse-string suture is inserted into the open end of the distal rectum and drawn around the shaft. It is important that the bites of any purse-string suture are not too large and that any excess tissue has been cleared off the gut that overlaps the ends; otherwise, satisfactory approximation of the two ends is prevented (Figure 14.15). Staples that are fired through too great a bulk of tissue will be insecure. A monofilament non-absorbable suture that slides atraumatically through the tissue is most suitable for this purse-string suture. The head of the gun is interlocked with the shaft and the ends apposed. The device is then 'fired'. This delivers two circles of staples to form the anastomosis. A circular blade amputates the excess tissue within the staple line as two 'doughnut' rings. The stapling device can then be removed. The head has to traverse the anastomosis, and with some instruments the head flips into a vertical plane to ease removal.

There are many possible variations of the above procedure when access to an orifice is not possible or when an end-to-side anastomosis is favoured. The main instrument may be introduced through a separate incision in the lumen (Figure 14.16). Alternatively, the main instrument, or the head, may be introduced through an open cut end (Figure 14.17). The opening for the introduction of the main instrument cannot be closed until after completion of the circular anastomosis, and the surgeon must consider whether access for this closure will still be possible.

A circular stapling device may also be used to transect and re-anastomose an intact segment of the gastrointestinal tract. The instrument is introduced locked but separated so that tissue can be drawn into the gun before the gun is closed. The instrument is fired and a single 'doughnut' of tissue excised, and continuity is restored by a circular stapled anastomosis. This technique can be used for oesophageal transection for oesophageal varices (see Chapter 21). The tissue is invaginated by an external ligature around the oesophagus (Figure 14.16). A similar principle is utilised in a stapled haemorrhoidectomy, wherein a circumferential suture, confined to the mucosa, is inserted *per anum* and used to draw the mucosa and submucosal haemorrhoidal plexus into a specially adapted circular stapling device (see Chapter 24).

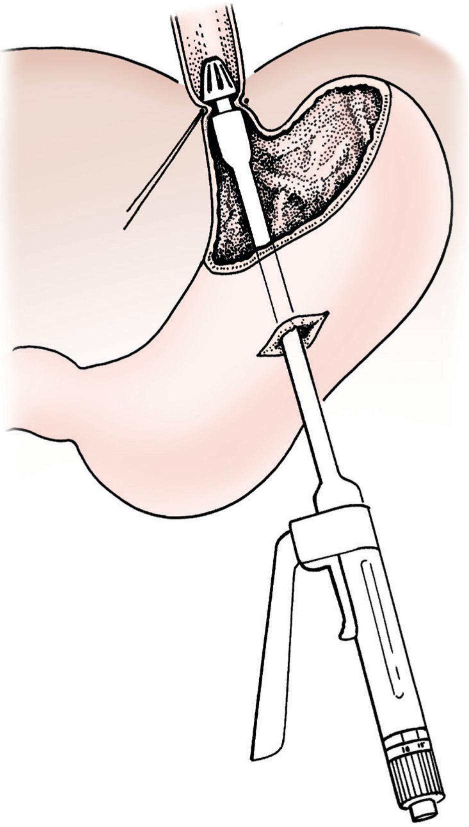

Figure 14.16 *The circular stapler has been introduced through a separate gastrotomy to perform an oesophageal transection and reanastomosis for varices.*

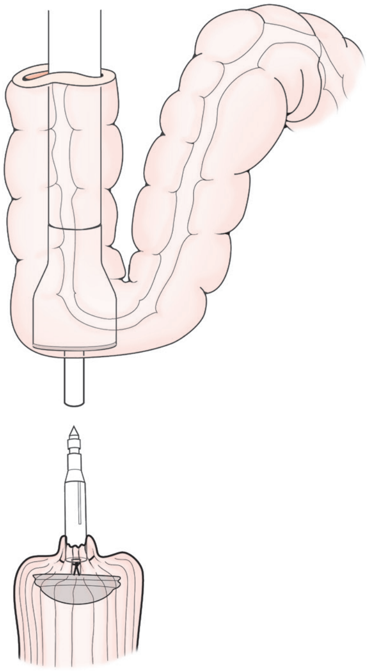

Figure 14.17 *The circular stapling device has been introduced through the open end of the colon for a side-to-end anastomosis onto the top of the rectum. Access to the open end of the colon to close it may, however, be difficult.*

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15

EMERGENCY ABDOMINAL SURGERY

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INTRODUCTION

Emergency abdominal surgery differs from elective surgery in that a surgeon is often forced to intervene with only a provisional diagnosis but with the knowledge that surgical intervention is urgent. The value of exhaustive investigations has to be balanced against any deterioration that may occur during the inevitable delay. A short delay, for both active resuscitation and preliminary investigations, is, however, usually beneficial as surgery on severely shocked or septic patients carries a high mortality. There are also situations where during this period the underlying pathology is clarified and found to be more appropriately managed conservatively or by some alternative non-surgical intervention. Intensive preoperative resuscitation has the potential to improve physiological status and reduce the risk of perioperative death, but unfortunately, deterioration can also occur. Cardiovascular stability and adequate tissue perfusion may not be attainable in the presence of continuing haemorrhage, and as overall blood loss rises, coagulopathy will inevitably develop. Infarction of tissue already compromised by ischaemia or excessive dilatation may result in perforation and sepsis, and absorption of toxic products from any dead tissue will also continue (see Chapter 12). The timing of surgery is therefore very important. The surgeon, aware of the deteriorating intra-abdominal situation, is often impatient to operate on a patient still unfit for major intervention. The anaesthetist, in contrast, may strive too long to optimise a patient preoperatively in situations where deterioration is inevitable until the underlying pathology has been addressed. Any apparent conflict of interest needs discussion and compromise. Despite the value of intensive preoperative resuscitation of very ill patients, the 'window of opportunity' must not be missed and delay beyond 4 hours is usually counterproductive. An adequate level of postoperative care must also be planned for such cases.

Emergency abdominal surgery may be required for major, or persistent, intra-abdominal haemorrhage, whether spontaneous or as a sequela to abdominal trauma. It is also necessary for any traumatic, infective or ischaemic condition in which the integrity of the gastrointestinal wall as a barrier is threatened or has already been breached. Surgery for intestinal obstruction is covered in Chapter 23, but the initial management of the obstruction is conservative unless the gut wall is threatened by ischaemia. Similarly, intra-abdominal infection, in the absence of any threat to gastrointestinal integrity, can often be successfully managed conservatively with antibiotic therapy. Inflammation will resolve and even small collections of pus can be reabsorbed. Larger collections of pus must be drained, but surgery can be avoided in many situations by the use of image-guided percutaneous drainage techniques.

EMERGENCY LAPAROTOMY FOR NON-TRAUMATIC HAEMORRHAGE

Immediate intervention is indicated for massive intra-abdominal haemorrhage, which may be intraluminal but more often is intraperitoneal or retroperitoneal. Surgery is required in parallel with ongoing resuscitation, as any delay is detrimental when the requirement for blood replacement is massive and continuous. *Urgent* intervention is indicated in some instances for continuing or recurrent smaller bleeds. Preliminary investigations may have already defined the problem and an alternative endoscopic or radiological intervention has been either considered inappropriate or has been tried and failed.

Spontaneous intraperitoneal and extraperitoneal haemorrhage

A shocked hypovolaemic patient without a history of trauma or external blood loss may have had a massive spontaneous intraperitoneal bleed. The most likely underlying pathology will depend on the age and sex of the patient. Ruptured ectopic pregnancies (see Chapter 27) and ruptured abdominal aortic aneurysms (see Chapter 7) account for the majority of cases. Rarer causes include haemorrhage from a liver tumour, rupture of a splenic artery aneurysm and spontaneous rupture of a spleen rendered more fragile than normal by glandular fever, malaria or adjacent pancreatitis. In some situations the bleeding initially may be contained retroperitoneally. The patient remains haemodynamically stable for a variable period before free haemorrhage into the peritoneal cavity ensues. If the diagnosis is in doubt, a computed tomography (CT) scan is helpful, but the delay for imaging is contraindicated in the unstable patient, and the surgeon must proceed directly to laparotomy. The abdomen is opened through a generous midline incision and the surgery is then that of the underlying condition, as discussed in the relevant chapters. However, first the surgeon must arrest the bleeding by a clamp, digital pressure or packing to allow the anaesthetist to stabilise the patient. Uncontaminated intraperitoneal blood may be filtered and used as an autotransfusion (see Appendix II). Unfortunately, unless this is a procedure in common use in an operating theatre, attempts to institute it in an occasional emergency usually fail.

Elderly patients on long-term anticoagulation are at risk of a spontaneous intra-abdominal haemorrhage. Presentations vary, but are seldom sudden or dramatic. The patient is more often anaemic than profoundly shocked. The haemorrhage is usually within the mesentery, the anterior abdominal wall or retroperitoneum, where the expanding haematoma produces pressure effects and pain. The haematoma also activates and consumes clotting factors and causes further derangements of coagulation. Haemorrhage may have commenced, with the international normalised ratio (INR) just above the therapeutic range of 2 –3, but this continues to rise and levels of 8 or above are then not uncommon. The first priority is to restore blood clotting by reversal of anticoagulation (see Appendix I), and no surgical intervention may then be necessary. However, if there is a large haematoma, evacuation may be justified, especially as normal coagulation may be difficult to achieve with the haematoma *in situ*, but this surgery must be covered with a fresh-frozen plasma infusion.

POSTOPERATIVE HAEMORRHAGE

Primary haemorrhage

Haemorrhage during the first 24 hours after abdominal surgery may be dramatic and sudden, indicating the failure of a ligature on a major vessel, and immediate reoperation is indicated. More often, only a small vessel is involved but if bleeding continues, then surgical intervention may have to be considered. Clotting abnormalities should be checked and corrected, and it should be remembered that a large haematoma will derange the clotting factors. If bleeding continues, re-exploration is indicated. Often a haematoma is found and evacuated, but no bleeding vessel or persistent haemorrhage can be identified. The abdomen is closed with a suction drain to the area from which the haematoma was evacuated, and further haemorrhage seldom ensues. If an actively bleeding vessel is identified, it is ligated but occasionally, although significant persistent bleeding is found, it is not possible to identify or ligate specific bleeding points. In this situation, packing with large gauze swabs, which are removed at a second operation around 48–72 hours later, may be the best option.

Secondary haemorrhage

Haemorrhage around 10 days after surgery is very difficult to deal with satisfactorily at reoperation. Secondary haemorrhage may occur in the pelvis after rectal surgery or from the posterior wall of the lesser sac, either as a complication of pancreatitis or after gastric surgery. The haemorrhage is associated with infection and the tissue is friable. Sutures and ligatures tear through the tissue, and packing is normally the only practical operative manoeuvre. Ligation of a major feeding vessel at some distance from the bleeding point may be successful but, if interventional angiography facilities are available, selective embolisation offers a better alternative.

Haemorrhage into the lumen of the gastrointestinal tract

Occasionally, the surgeon is forced to operate for massive and continuous intraluminal blood loss without the benefit of preoperative endoscopy, but more often the surgery can be delayed for full resuscitation and endoscopic or radiological investigations. The surgical management of upper gastrointestinal haemorrhage is discussed in Chapter 18 and that of lower gastrointestinal haemorrhage in Chapter 23.

Gynaecological and obstetric haemorrhage

See Chapter 27.

EMERGENCY SURGERY FOR PERITONITIS

The decision to operate on a patient with an 'acute abdomen' and suspected peritonitis is always based on a range of clinical, haematological and biochemical factors, supported by increasingly sophisticated imaging. CT or ultrasound scans may be useful where there is diagnostic uncertainty, but should be avoided where the decision that urgent surgery is required is clear and investigations may merely delay treatment. Often, however, clinical examination of the abdomen is still one of the most sensitive diagnostic tools. Inflammation of the parietal peritoneum triggers the tenderness and reflex guarding of peritonism. The clinical signs may be elicited over the whole anterior abdominal wall, suggesting a generalised peritonitis, or they may be restricted to one quadrant of the abdomen, suggesting a localised peritonitis. Since the signs are secondary to peritoneal inflammation, they may be reduced or even absent in a patient who is immunosuppressed by steroids or chemotherapy. Diagnosis is not always easy; some patients have referred pain and reflex guarding from supradiaphragmatic, scrotal or retroperitoneal pathology. Basal pneumonia, myocardial infarction and testicular torsion can all mimic a surgical acute abdomen, as can the pain from a retroperitoneal pathology, whether an obstructed kidney or the initial contained rupture of an aortic aneurysm causing tissue distension. Some intra-abdominal pathologies, such as biliary colic and the capsular distension of a congested liver, can produce signs of peritonism in the absence of peritoneal inflammation. It must also be remembered that some medical pathologies, including sickle cell crises and porphyria, can produce abdominal pain and confusing clinical signs. Ketoacidosis in diabetic patients may present with an apparent surgical acute abdomen, and this is particularly common in children. The root pain from shingles precedes the vesicular rash and may also cause diagnostic confusion.

Generalised peritonitis

When the signs of peritoneal irritation extend over the whole abdominal wall, this usually indicates the presence of either free intraperitoneal pus or gastrointestinal contents or, alternatively, multiple loops of ischaemic or infarcted bowel. An emergency laparotomy or laparoscopy is usually indicated, but the surgeon must first consider other conditions that may mimic peritoneal inflammation in addition to those causes of general peritoneal inflammation for which surgery is not indicated. Pancreatitis should be excluded when the aetiology of the peritonitis is in doubt. A serum amylase measurement, which can normally be available within 1 hour, may prevent inappropriate surgery. The inflammation from a severe gastrointestinal infection may also cause a generalised peritoneal reaction. *Campylobacter* is the microorganism that most often mimics a surgical acute abdomen in the UK.

Surgical access

When a decision to operate has been made, there is often still only the incomplete diagnosis of 'acute abdomen'. Palpation of the relaxed abdomen, once the patient has been anaesthetised, may reveal a mass that was not previously apparent. This may help to elucidate the diagnosis and indicate the most appropriate surgical approach. A midline incision, which can be extended either up or down as necessary, is the most versatile but if a perforated appendix is strongly suspected as the cause of the generalised peritonitis, it is reasonable to make a small appendix incision. If the diagnosis is wrong, it may be possible to deal with the problem by a limited muscle-cutting extension, but more often it is safer to close the initial incision and make a separate midline laparotomy. Laparoscopy is gaining favour as the initial intervention. The advantage is that even if the underlying pathology cannot be dealt with laparoscopically, the situation can be assessed and the abdomen opened with the most suitable incision.

ISCHAEMIC OR INFARCTED TISSUE

If ischaemic gut is encountered, a mechanical cause of strangulation, by internal herniation or volvulus, should be sought. Mechanical release of a restriction or derotation of a mesentery restores the circulation and the viability of the segment can be confirmed. However, restoration of circulation to infarcted tissue should be avoided if at all possible, as the products of the dead tissue, when released into the circulation, will cause further systemic insult. Infarcted tissue must be resected and the surgeon may have to proceed with a small or large bowel resection, a cholecystectomy, a gastrectomy or an oophorectomy, as described in the following chapters. On occasion, ischaemic but non-infarcted bowel is encountered due to a mesenteric vascular thrombus or embolus, and restoration of perfusion may still be an option (see Chapters 7 and 23). Unfortunately, however, the ischaemic damage from mesenteric vascular accidents is usually already irreversible at the time of laparotomy. The ischaemia associated with a severe intramural infective process rapidly progresses to infarction and is irreversible. Ischaemia from a severe intramural vasculitic process usually follows a similar course.

PURULENT PERITONITIS

Free intraperitoneal pus or gastrointestinal contents should be removed from the peritoneal cavity by suction, and the source of the contamination located. This is usually obvious, and the surgical options for the various pathologies are discussed in the following chapters. If the cause of the peritonitis is not immediately apparent, the colour, odour and consistency of the pus can give helpful clues. Thin, bile-stained pus suggests an upper gastrointestinal perforation, white coloured pus may have a gynaecological source, and faeculent pus suggests a colonic perforation. Gastric acid induces an intense peritoneal reaction, even before any secondary infection develops, and at operation for a perforated duodenal ulcer the peritoneal fluid may not be purulent. Perforation can occur into the lesser sac, and a generalised peritonitis then only follows as the contamination spreads. This must be remembered when no gastrointestinal perforation can be found. A perforation into the lesser sac can only be excluded if the lesser sac is opened (see Figure 14.4, p. 230).

When there is pelvic pus, the underlying pathology may be difficult to determine, as any structure lying within the pelvis will be secondarily inflamed. The pus from a ruptured diverticular abscess may thus be erroneously ascribed to infection of the appendix or Fallopian tube. If a generalised or pelvic peritonitis from salpingitis is discovered, the pus should be removed by suction and the patient treated with antibiotics. A tubo-ovarian abscess or an underlying septic abortion, however, will require further intervention. Other gynaecological pathology, which can present as an emergency leading to a laparotomy by a general surgeon, is discussed further in Chapter 27.

Occasionally, no cause for a purulent peritonitis can be found. In these circumstances all the surgeon can do is to be sure that no pathology has been missed, remove all pus by suction and send a pus sample for culture. The peritoneal cavity should be washed out with saline or with an antibiotic wash (e.g. tetracycline, 1 g/litre saline). The abdomen is closed and broad-spectrum antibiotics continued until the sensitivities of the causative organisms are known. *Primary tuberculous*, *streptococcal* and *pneumococcal peritonitis* are now rare in the developed world, although primary peritonitis is a recognised complication in patients undergoing peritoneal dialysis.

- In *acute tuberculous peritonitis* the peritoneal exudate is clear and straw coloured. In addition, tuberculous nodules and lymphadenopathy are apparent. If tuberculosis is suspected, tissue samples should be taken for histology and pus sent for tuberculosis culture.
- In *chronic tuberculous peritonitis* the laparotomy has usually been undertaken for small bowel obstruction, and multiple adhesions rather than exudate predominate.
- The fluid in *streptococcal peritonitis* is turbid and may be blood stained.
- In *pneumococcal peritonitis* the pus is thick and greenish yellow.

Occasionally, although the preoperative diagnosis of peritonitis is not upheld at surgery, the correct diagnosis is immediately obvious. The enlarged lymph nodes of mesenteric adenitis may be easily palpable, Henoch–Schönlein purpurae may be visible on the serosa of the bowel or patches of saponification indicating acute pancreatitis may be apparent in the omental fat. No operative procedure is helpful, and the abdomen is simply closed. When no intraperitoneal pathology can be found the surgeon must reconsider the other conditions that can mimic the surgical acute abdomen.

POSTOPERATIVE PERITONITIS

This is difficult to diagnose, as local symptoms and signs are masked by tenderness from the wound. In addition – and especially in the elderly – the systemic toxicity can take the form of general cardiac and respiratory problems, with associated neurological deterioration, and the underlying surgical cause is easily missed. The time since surgery, and the nature of that surgery, provide some indication of the most likely underlying pathology. Infarction of a major segment of the gastrointestinal tract or pancreatitis usually present early, whereas an anastomotic dehiscence most often occurs between the 5th and 10th day. An anastomotic leak at some sites can be confirmed by a water-soluble contrast study, and the management is almost invariably operative. The surgery of anastomotic dehiscence is discussed further in the following chapters. In general, however, repair of a delayed anastomotic leak is seldom practical, and emergency surgery consists of drainage and some form of diversion of the gastrointestinal contents, so that further contamination of the peritoneal cavity is prevented.

THE ACUTE ABDOMEN IN INTENSIVE CARE

When an intra-abdominal catastrophe is suspected in a critically ill patient in intensive care, diagnosis is difficult as these patients are often on mechanical ventilation, sedated and receiving inotropic support. Any clinical abdominal signs are masked and signs of the systemic inflammatory response syndrome (SIRS) are modified, or suppressed, by intensive management.

The patient who has had recent trauma or abdominal surgery is at increased risk of an intra-abdominal complication. Previously unsuspected blunt abdominal injury may have occurred in addition to the major neurological or thoracic trauma for which the patient is receiving treatment. The left colon may become ischaemic following abdominal aortic surgery or an anastomosis may have leaked after gastrointestinal surgery. Postoperative haemorrhage is difficult to diagnose in patients who are cardiovascularly unstable from multiple causes. There may be a cardiogenic or septicaemic component to the hypotension. In addition, fluid shifts and the haemodilution of overhydration make the interpretation of hypovolaemia or of a falling haemoglobin concentration difficult. A return to the operating theatre adds little to the total physiological derangement in a severely ill patient on ventilatory support, and more is lost by delaying a second look than in performing an unnecessary further procedure. When there is not a recent laparotomy wound to re-open, laparoscopy should be considered as a less invasive alternative.

Intra-abdominal surgical complications are increasingly recognised in the non-surgical intensive care patient. Mesenteric vascular thrombosis is common. Immunosuppressed patients receiving cytotoxic chemotherapy may develop right-sided neutropaenic colitis necessitating a right hemicolectomy. Acalculous cholecystitis, which usually requires an emergency cholecystectomy, is a common cause of an acute abdomen in a patient in intensive care and is not related to recent abdominal surgery. Primary peritonitis, as a complication of peritoneal dialysis, is treated conservatively unless there is evidence of another intra-abdominal pathology requiring surgical intervention.

Localised peritonitis

A more confident provisional diagnosis is possible when there are signs of peritoneal inflammation restricted to one quadrant of the abdomen, and the surgeon is able to be more selective in proceeding to surgery. Urgent intervention is indicated if the integrity of the gastrointestinal wall is threatened, whether the underlying pathology is infective or ischaemic. CT imaging is very sensitive at detecting the small volumes of free intraperitoneal air associated with a localised perforation. It is less sensitive at determining that perforation is imminent, and normal appearances at imaging should not be allowed to inappropriately delay treatment in a patient who is clinically deteriorating.

INFECTIVE PATHOLOGY

The history and the localised signs may suggest an infective inflammatory process in the gallbladder, the Fallopian tubes, the appendix or in a segment of sigmoid diverticular disease. All of these conditions may settle spontaneously or respond to antibiotic therapy. Early surgery is indicated in conditions that carry a high risk of progression to peritoneal contamination with gastrointestinal contents or faecal peritonitis. Thus, the management of appendicitis is operative and that of salpingitis conservative. Cholecystitis and colonic diverticulitis will usually settle on conservative management with antibiotics. If, however, deterioration on medical management is occurring, the surgeon must not forget the potential for rupture and generalised peritonitis. Emergency cholecystectomy and sigmoid colectomy are described in the relevant chapters.

ISCHAEMIA

If the peritonism is of ischaemic origin, then intervention before infarction, perforation or systemic sepsis is the overriding surgical concern. Localised peritonism, in association with a small bowel obstruction, usually suggests an ischaemic loop of small bowel and is an indication to abandon conservative management. In a large bowel obstruction or an exacerbation of pan-proctocolitis, right iliac fossa peritonism indicates compromised caecal perfusion, impending caecal rupture and the need for emergency surgery. However, any inflammatory process involving the full thickness of the bowel wall can induce peritonism from direct involvement of the peritoneum in the inflammation. A segment of Crohn's disease, causing both an obstruction and local peritonism, can be difficult to differentiate preoperatively from a strangulated loop of bowel. Other non-ischaemic full-thickness inflammatory conditions of the bowel, including tuberculosis, typhoid fever and amoebic dysentery, pose similar difficulties with interpretation of signs, as local peritonism may indicate neither ischaemia nor incipient perforation. However, sometimes surgical exploration may be the only way to rule out a complication of an inflammatory pathology. The serious implications of undue delay must be balanced against the desire to avoid unnecessary surgery.

INTRAOPERATIVE DILEMMAS IN THE ACUTE ABDOMEN

The surgeon may find unexpected surgical pathology. If this requires operative intervention, then usually there is simply a change of plan, although an incision may have to be enlarged, the anaesthetist may require additional monitoring facilities or blood for transfusion and specialist surgical help may have to be sought. However, for many surgical conditions there is a variety of operative solutions. In the emergency situation the ideal surgical procedure may be contraindicated by the poor condition of the patient or the lack of specialist expertise or facilities, and considerable surgical judgement is required. The situation may be further complicated if the primary pathology is a malignancy. If the tumour is still potentially resectable, the emergency surgery must not jeopardise the chances of cure. Conversely, optimal palliation must be considered when a surgical complication of an advanced malignancy is encountered (see Chapter 16). It must also be remembered that intra-abdominal tuberculosis can mimic disseminated intraperitoneal malignancy.

Some intraoperative dilemmas are related to the finding that surgery was not indicated. If a non-surgical pathology is revealed, such as mesenteric adenitis or salpingitis, the abdomen is simply closed and the patient managed conservatively. More problematic, however, are the situations that might have been managed by a period of initial conservative treatment so that emergency surgery could have been avoided. Where a laparoscopy has been carried out it is often still appropriate to proceed with conservative management, but if a laparotomy incision has been made, then a definitive operation may be preferable, rather than risking the need for a second laparotomy a few days later if the condition has not settled. If *cholecystitis* is found unexpectedly at laparotomy, a cholecystectomy is justified even for a mildly inflamed gallbladder in order to avoid the need for a further procedure should cholecystectomy be necessary at a later date. When an initial appendicectomy incision has been made, the decision is less straightforward. A short segment of severely inflamed *Crohn's disease* should be resected, but the decision is more difficult in extensive disease. If *diverticulitis* is encountered unexpectedly, the decision whether to proceed with a major resection is difficult if the condition is relatively mild. If the left iliac fossa is merely drained, the abdomen closed and the patient treated conservatively, a minority will return for emergency surgery during the same hospital admission. These patients would have been served better by a resection at the initial laparotomy. However, if, instead, a difficult sigmoid resection is performed in a patient whose diverticulitis would have settled on conservative treatment, this decision may also have been suboptimal. An emergency colectomy carries greater morbidity, a higher chance of a stoma and, if an underlying cancer is present, a reduced chance of a curative resection. Intraoperative decisions have to be made according to a variety of factors, including the general condition of the patient, the experience of the surgeon and the available resources.

SURGERY FOR THE DRAINAGE OF LOCALISED PUS

Localised intra-abdominal pus may be either intraperitoneal or retroperitoneal or trapped within organs. Small collections of pus may be absorbed and effective antibiotics have increased the potential for conservative management. Any significant collection still requires drainage, as it must be remembered that antibiotics cannot penetrate into an abscess cavity.

Intraperitoneal pus

Localised collections of pus may occur around any intra-abdominal infective pathology that has been walled off from the general peritoneal cavity by omentum or loops of bowel. This is encountered in appendicular and diverticular abscesses, the surgical management of which is discussed in Chapters 22 and 23. Any minor leak of gastrointestinal contents secondary to a perforation or anastomotic failure may become walled off in a similar manner. Localised collections of pus can also persist after the resolution of a generalised peritonitis, and are classically encountered in the pelvis and subphrenic space. Infected haematomas following intra-abdominal surgery are another source of intra-abdominal abscesses. In the pre-antibiotic era, localised intra-abdominal pus was both a common and life-threatening condition requiring treatment by urgent surgical drainage. Prophylactic antibiotic cover for gastrointestinal surgery, and therapeutic courses of antibiotics when there is established infection, have greatly reduced this complication.

A patient with suspected intra-abdominal infection is treated initially with intravenous antibiotics. If resolution does not follow, an ultrasound or CT scan may demonstrate the presence and site of a collection of infected material. Image-guided percutaneous drainage of the collection is now preferred to open exploration in most circumstances, and can be employed for pelvic, subphrenic and localised intraperitoneal abscesses. However, if this facility is not available, open surgical drainage may still be required.

PELVIC ABSCESS

A pelvic collection can sometimes be confirmed clinically by a palpable boggy swelling in the rectovesical pouch on digital examination. Abscesses that can be felt in this way will usually drain spontaneously per rectum or per vaginum. This may be the safest management, as surgical drainage, either per rectum or at a laparotomy, can endanger friable, inflamed small bowel loops in the pelvis. Percutaneous image-guided drainage is increasingly employed for abscesses in which imminent spontaneous discharge seems unlikely.

SUBPHRENIC ABSCESS

Harmless spontaneous drainage of subphrenic pus does not occur. More frequently, the abscess persists with general systemic toxicity, but occasionally drainage occurs spontaneously through the diaphragm into the lung. Before sophisticated imaging, subphrenic abscesses were difficult to diagnose and greatly feared as a surgical complication with a high mortality. Hiccoughs, a high right hemidiaphragm and right basal lung signs increased suspicion, but diagnosis was frequently based on the maxim, 'Pus somewhere, pus nowhere else, pus under the diaphragm.' The classic air fluid level was unfortunately seldom present. The abscesses were described as anterior and posterior, and were also divided into true subphrenic and subhepatic collections. Traditionally, attempts were made to drain the pus without entry into the peritoneal cavity, as this was believed to be safer. The surgical approaches for these procedures are now only of historical interest because if surgical drainage is indicated, either laparoscopy or an approach via an upper midline laparotomy incision is now recommended. This allows access to both the suprahepatic and subhepatic spaces bilaterally, and often there is more than one collection. In addition, a subphrenic abscess may be the result of an anastomotic leak after upper gastrointestinal or biliary surgery. If the peritoneum is opened, an anastomosis can be inspected and, if disrupted, decisions taken on the optimal management of the complication that has caused the abscess.

Retroperitoneal pus

A perinephric abscess may be secondary to an infected kidney, but may also occur as a primary blood-borne staphylococcal infection. Similarly, a psoas abscess may be secondary to a posterior colonic perforation or a vertebral osteomyelitis, but may also be a primary myositis. A loin or anterolateral extraperitoneal approach will be suitable for drainage of the pus. Infected retroperitoneal and lesser sac collections associated with pancreatitis are considered in Chapter 20.

Pus trapped within intra-abdominal organs

Pancreatic and liver abscesses require urgent, rather than emergency, management (see Chapters 20 and 21) but emergency intervention is required for pus trapped within an obstructed hollow viscus. An empyema of the gallbladder and a pyometrium are examples, but the greatest danger is from infection in an obstructed biliary system or kidney.

Cholangitis is often initially diagnosed as a cholecystitis and treatment initiated with antibiotics and general resuscitative measures. The swinging fever, severe toxicity and deepening jaundice alert the surgeon to the more serious diagnosis. Ultrasound imaging may show a stone impacted in the common bile duct. Emergency drainage of the biliary tract is essential and may be achieved by endoscopic sphincterotomy to allow the impacted stone to pass. If this is not available, then open or laparoscopic exploration of the common bile duct to allow free drainage of bile is mandatory (see Chapter 19).

Pyonephrosis also requires urgent drainage of the obstructed hydronephrotic renal pelvis. The underlying pathology may be a mechanical obstruction from a ureteric calculus or a functional obstruction from a congenital abnormality of the pelviureteric junction. The situation is usually managed by image-guided percutaneous drainage of the dilated renal pelvis. If radiological skills are not available, the urologist may be able to pass a ureteric stent past the obstruction at cystoscopy. A general surgeon without urological training, who is faced with this problem, may be forced to operate directly on the ureter to remove the calculus or on the renal pelvis to establish nephrostomy drainage (see Chapter 26).

ABDOMINAL TRAUMA: GENERAL PRINCIPLES

Abdominal trauma may occur as a result of either blunt or penetrative injury. Many patients have associated chest, skeletal and head injuries, and cooperation with all specialists involved is essential. Assessment and initial management, along the principles of the Advanced Trauma Life Support system (ATLS), are important and should ensure that other relevant injuries are not overlooked.[1]

- *Blunt trauma* includes direct blows, crushing injuries, blast and deceleration forces. Any intraperitoneal organ may be ruptured without superficial evidence of trauma. The history of the mechanism of injury is important in predicting the likely pattern of internal damage.
- *Penetrating trauma* includes knife and bullet wounds and, again, the pattern of damage varies with the object that has penetrated the abdomen. In gunshot injuries, the velocity of a bullet is also important (see Chapter 4). The abdominal cavity is most frequently breached from an external wound in the anterior abdominal wall, but entry into the peritoneal cavity and damage to intra-abdominal organs can also occur from penetrating wounds in the thorax, the loin, the buttock or the perineum.

Surgery for abdominal trauma is indicated for suspected breaches in the gastrointestinal tract and for continuing haemorrhage. Less commonly, an intra-abdominal vascular injury may present with distal ischaemia (Figure 15.1).

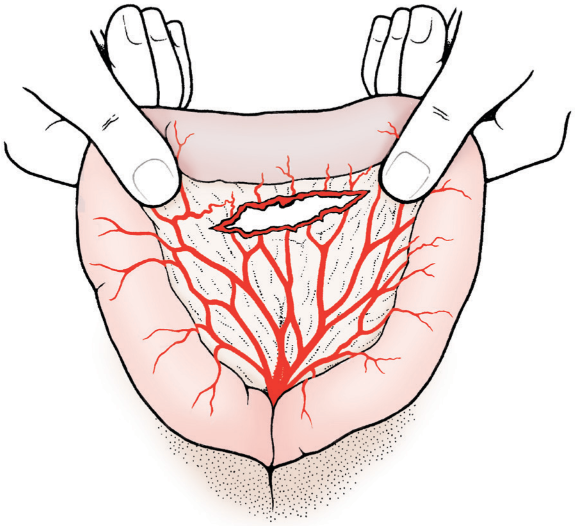

Figure 15.1 *This mesenteric tear will result in an ischaemic segment of small bowel.*

The decision to explore the abdomen following trauma is based on clinical judgement, often supplemented by imaging. An immediate laparotomy may be required for massive intra-abdominal haemorrhage. However, in most instances the urgency is less acute, and unless any delay is obviously detrimental, initial stabilisation and evaluation are beneficial. In addition, in many patients it may not be clear initially whether surgical intervention is indicated or not. The traditional teaching was that all penetrating trauma of the abdomen should be explored, whereas after blunt injury, where the incidence of intra-abdominal injury is lower, a patient could be observed and a laparatomy only undertaken if there was any evidence of peritonitis or intraperitoneal bleeding. It is known, however, that many injuries to the liver, spleen and kidney may bleed significantly initially and then stop and that no surgical intervention is required. Experience from the USA and South Africa, where there is a heavy burden of penetrating abdominal trauma, has shown repeatedly over the past 50 years that an expectant policy may also be safe in penetrating trauma with a reduction in unnecessary operations.[2] Although most surgeons are now comfortable with an expectant policy in a stab wound – especially if there is doubt as to whether the peritoneum has even been breached – most surgeons in the UK still believe that in gunshot wounds exploration is safer, as the risk of injury to a hollow viscus is significantly higher.[3] This is despite continuing evidence that a selective policy, with facilities for rapid intervention if required, is a safe alternative.[4]

During the period of active observation, further assessment and treatment are continued. Blood and fluid replacement must be adequate for good tissue perfusion, but aggressive overperfusion must be avoided as it may be a factor in encouraging re-bleeding from traumatised tissue.[5] A major pelvic fracture, with opening of the pelvic ring, can be associated with massive pelvic venous bleeding. The first line of management is external stabilisation of the pelvic fracture to prevent further opening of the ring and to compress the torn pelvic veins, and not an early laparotomy (see Figure 5.8, p. 71).

Clinical assessment

Laparotomy or laparoscopy is indicated for suspicion of injury to a hollow viscus. A clinical assessment of peritoneal irritation, and the signs of SIRS, are often more accurate in assessing an injury to the gut than sophisticated imaging. However, early clinical signs may be minimal in retroperitoneal duodenal or colonic injuries associated with penetrating trauma to the back or flank. These injuries can also be missed at laparoscopy, or even laparotomy, if not specifically sought. When multiple injuries are present, particularly if these include the head or chest and the patient is receiving ventilatory support, the clinical picture is often misleading. In these situations it is often safer to explore on a lower level of suspicion than to continue with an expectant policy. Laparoscopy may be a useful diagnostic tool in abdominal trauma, but for the repair of many of the injuries encountered an open laparotomy is a more appropriate approach for the majority of surgeons.

Laparotomy may also be required for continuing haemorrhage but, as bleeding will frequently cease spontaneously, selected patients can be managed conservatively. The total estimated blood loss and the rate and pattern of bleeding are all important in this decision. Repeated episodes of bleeding, with temporary haemodynamic instability, are more worrying than a slower continuous haemorrhage. The organ injured and the severity of that injury shown on imaging may be more important indicators of the need for intervention than the total blood loss.

Imaging

Imaging procedures include the following:

- *Plain abdominal* and *chest X-rays* provide some limited information. Fractures of the lower ribs indicate that there has been an injury that had the potential to damage the liver or spleen, while pelvic fractures indicate potential injury to pelvic organs. Obliteration of a psoas shadow and fractures of the bodies or transverse processes of the upper lumbar vertebrae are markers of significant retroperitoneal trauma. The X-ray may show a diaphragmatic rupture or it may demonstrate free intraperitoneal or retroperitoneal gas, thus confirming a breach in the gastrointestinal tract.
- *Focused assessment with sonography for trauma* (FAST) forms part of the initial assessment in many trauma centres. However, false negatives and positives occur and there is still doubt as to the influence the results have on further management.[6]
- An *intravenous urogram* (IVU) provides some assessment of the severity of the damage to a kidney but, more importantly, it confirms both the presence and the function of the contralateral kidney; however, a CT scan will give both this and additional information.
- *CT scanning* is of limited value in excluding a bowel injury, but is an excellent modality for imaging solid organs and the retroperitoneum. If performed with contrast, it can give valuable information not only on the anatomical damage to the liver, spleen, kidney or pancreas, but also information on renal function, major vessel damage and the presence of arterial bleeding into a haematoma. It is therefore a more valuable imaging modality than an IVU in renal trauma, although if a renal injury is seen on the initial scan, a delayed scan or plain film to look for extravasation of contrast from the renal collecting system is also required. The initial and serial CT appearance of solid organ damage is an increasingly useful predictor of the likely success of conservative management. It may also indicate situations where it is possible to stop the haemorrhage by selective embolisation and avoid surgery. Embolisation occludes the vessels at the site of haemorrhage, whereas surgical ligation of the main feeding artery does not take into account any additional collateral inflow.

Peritoneal lavage

This initial investigation has been virtually replaced by FAST scans. The increasing use of CT scans for the assessment of solid organ trauma, and of laparoscopy when concern persists over a bowel injury, has further reduced the potential of peritoneal lavage as a diagnostic tool. A dialysis catheter was inserted and normal saline run into the peritoneal cavity. The lavage solution was then drained and examined microscopically for cells. Gut contents, bacteria or more than 500 white cells per ml indicated peritoneal contamination from a bowel injury and rightly prompted surgical intervention. However, a ‘positive’ test for red blood cells (more than 100,000 per ml) may have led to unnecessary laparotomies.

LAPAROTOMY FOR TRAUMA

Significant intra-abdominal trauma can sometimes be managed more appropriately in a non-operative manner, as discussed below in relation to injuries to specific organs. When a surgeon decides on an emergency laparotomy, consideration must be given to other potential injuries. For example, an apparently minor chest injury with an undetected small pneumothorax may convert to a tension pneumothorax from the positive-pressure ventilation during a general anaesthetic for laparotomy. A chest drain should be inserted prior to induction of anaesthesia if this is felt to be a risk. An associated head injury must not be overlooked, and neurological monitoring will be difficult during anaesthesia. If a cervical spine injury cannot be excluded, the neck must be adequately immobilised.

A laparoscopy is valuable when there is continuing concern in a stable patient, but in most acute situations a midline incision is the most appropriate access. Blood or intestinal contents may be encountered, but a ‘clean’ peritoneal cavity does not exclude a significant injury. A perforation can easily be missed, and a careful inspection of the whole gastrointestinal tract is essential. A large collection of blood usually indicates damage to the spleen or liver or to a vessel in the mesentery or omentum. The first priority is haemorrhage control, followed by a thorough exploration to evaluate other injuries.

Injuries to the spleen

Minor injuries to the spleen were often not diagnosed before sophisticated imaging. Many healed without complication, but the occasional delayed splenic rupture occurred. Conservative management of splenic injuries is now the standard approach, especially in children, but the need for an emergency splenectomy for life-threatening haemorrhage must not be forgotten. Splenectomy is also indicated if a CT scan shows a major hilar laceration or a totally disrupted spleen, as even if bleeding has temporarily abated, significant further bleeding is almost inevitable. More minor injuries can be managed conservatively, particularly if bleeding is not excessive (Figure 15.2).

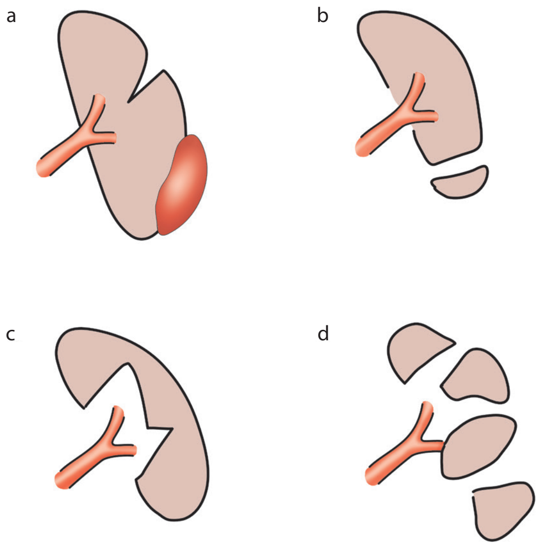

Figure 15.2 *Varieties of splenic injury that may be diagnosed preoperatively on CT scans. (a) A subcapsular haematoma and a peripheral laceration, both of which may heal without intervention. (b) An avulsion of a small portion of one pole; this injury is also compatible with splenic preservation. (c) A hilar laceration, which will almost certainly bleed again. (d) A fragmented spleen.*

Surgical approach

Before the start of an emergency laparotomy the splenic injury may have been confirmed or the diagnosis may only be of intraperitoneal haemorrhage. If major bleeding is continuing, rapid delivery of the spleen is essential. The left peritoneal leaf of the lienorenal ligament is incised or broken with a finger (see Figure 20.12a, p. 355), the spleen dislocated forwards and its vascular pedicle compressed between finger and thumb. This is safer than immediate clamping, which can injure the tail of the pancreas. When haemorrhage is under control, the tail of the pancreas is separated from the hilar vessels and the splenic artery and vein clamped and ligated separately (see Figure 20.12b, p. 355). Care must also be taken not to injure the splenic flexure of the colon. Elective splenectomy is discussed in Chapter 20, and emergency splenectomy differs only in the need to control haemorrhage rapidly.

Occasionally, a relatively minor splenic injury is encountered that has not bled significantly or has ceased to bleed and was not in fact the indication for the laparotomy. Splenic preservation should always then be considered. An injury that is still bleeding does not necessarily need a splenectomy either. After the spleen has been fully mobilised, with great care not to cause further damage, it may be possible to seal a peripheral laceration or an area of surface oozing with argon beam coagulation or by the application of a surface agent such as fibrin glue. A partial splenectomy is another option; the damaged upper or lower pole is excised, after formal ligation of the segmental vessels to the damaged portion. More aggressive splenorrhaphy techniques, such as splenic encasement with absorbable mesh, may have a place in paediatric practice, where splenic preservation is of greater importance. It must be remembered that in all situations where an injured spleen is left *in situ* it is important to monitor for re-bleeding.

Injuries to the liver

Haemorrhage from a liver laceration is often self-limiting, and uncomplicated healing can occur even in relatively major liver trauma. Non-operative management is now the treatment of choice for most liver injuries.[7] Intervention is indicated when haemorrhage is excessive, fails to cease spontaneously or a CT scan demonstrates an expanding central haematoma with arterial bleeding. This latter injury is unsuitable for conservative management, even if the patient is haemodynamically stable, as the expanding haematoma continues to destroy the surrounding normal liver and eventually ruptures intraperitoneally. Arterial embolisation should be considered for deep-seated arterial bleeding and the patient should be transferred, if at all possible, to a specialist liver surgery centre.

Surgical approach

When a surgeon performing a laparotomy for trauma encounters massive haemorrhage from the liver, it should be temporarily packed or manually compressed while the extent of the damage is assessed. The bleeding can be reduced by using the Pringle manoeuvre, in which a non-crushing clamp is placed across the free edge of the lesser omentum, occluding inflow from the hepatic artery and portal vein. This should not be left *in situ* for more than 1 hour. Continuing bleeding suggests an aberrant hepatic artery. It should be sought in the lesser omentum, where it arises from the left gastric artery, and it is also then temporarily occluded. Temporary aortic control above the coeliac trunk is occasionally necessary. If major haemorrhage continues from behind the liver, avulsion of hepatic veins from the inferior vena cava (IVC) is likely. Access is limited, and repair of these injuries is extremely difficult. A major resection may even be necessary before there is sufficient access for any venous repair. Temporary clamping of the IVC, above and below the liver, and temporary venous shunts have been attempted. A Foley catheter passed up into the right atrium can secure superior control. The chance of a successful outcome with such heroic manoeuvres is remote even in expert hands and, as judicious packing has been successful even in these major venous injuries, it is usually the best initial strategy. However, if bleeding cannot be adequately controlled, any window of haemodynamic stability should be used to transfer the patient to a specialised liver unit.

Usually, however, the measures described above provide temporary control of bleeding. Ideally, if the patient becomes more stable, the surgeon may then be able to mobilise the liver by division of the falciform, coronary and triangular ligaments. The liver can then be rotated into the wound, fully examined and a decision taken regarding surgical intervention or more formal packing. An individual bleeding vessel in a laceration can be ligated and a surface small vessel ooze can be treated by coagulation with diathermy or an argon beamer. Alternatively, fibrin glue can be used. These techniques are discussed in more detail in Chapter 21. Deep sutures in the liver to compress a bleeding laceration are not now recommended as they cause parenchymal strangulation, but they may still occasionally have a place (Figure 15.3). Formal packing of the liver has regained favour as the sole measure necessary to control haemorrhage in many injuries. Packing is designed to compress a laceration and should therefore be around the liver(Figure 15.4) and not into the laceration itself. Ideally, the liver should be the 'filling' of a sandwich with the packs, placed behind and in front, representing the 'bread'. Packs within a laceration are not recommended as they are liable to cause extension of a tear. (However, balloon catheters have been used effectively to tamponade the depths of a bleeding stab or low-velocity bullet track.) Packing has been found to be effective even in severe injuries involving the hepatic veins. Excessive packing may compress the vena cava and, except with a severe posterior injury, care must be taken to avoid this, otherwise venous return is compromised, leading to hypotension and peripheral engorgement. The packs should be removed at a second laparotomy at 24–48 hours, but this may be delayed longer if the clotting time or platelet count is still severely deranged. Discussion with, and possibly transfer to, a specialist liver surgery unit is recommended during this period.

Arterial bleeding cannot be controlled by packs. Accessible arteries can be ligated, but haemorrhage from an artery deep within the liver parenchyma may be inaccessible without a major resection. There may be no surface laceration, or bleeding from a laceration may have ceased following packing or the placement of sutures to appose the superficial portion of the laceration. The expanding haematoma will destroy surrounding normal liver. If this situation is diagnosed on a preoperative CT scan, selective embolisation can be most effective. Occasionally, selective hepatic artery ligation may be justified for arterial bleeding that cannot be stopped by other means. This measure is a last resort, but may prepare the situation to allow referral to an experienced surgeon to perform a resection.

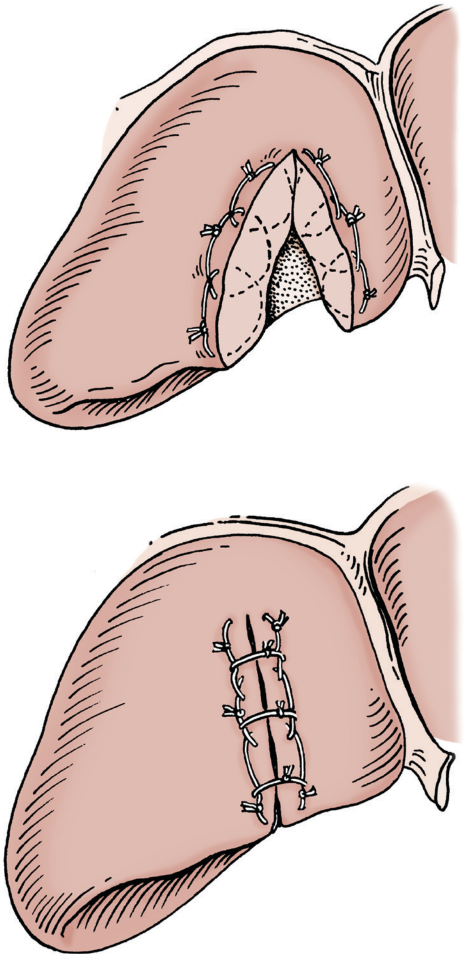

Figure 15.3 *Deep mattress sutures were traditionally used first to compress the edges of the laceration and arrest the haemorrhage, and then further sutures apposed the edges. The sutures cut through the liver parenchyma, but this was overcome by buttressing the sutures over omental fat and taking generous bites of liver substance. More precise techniques have superseded this method in almost all circumstances.*

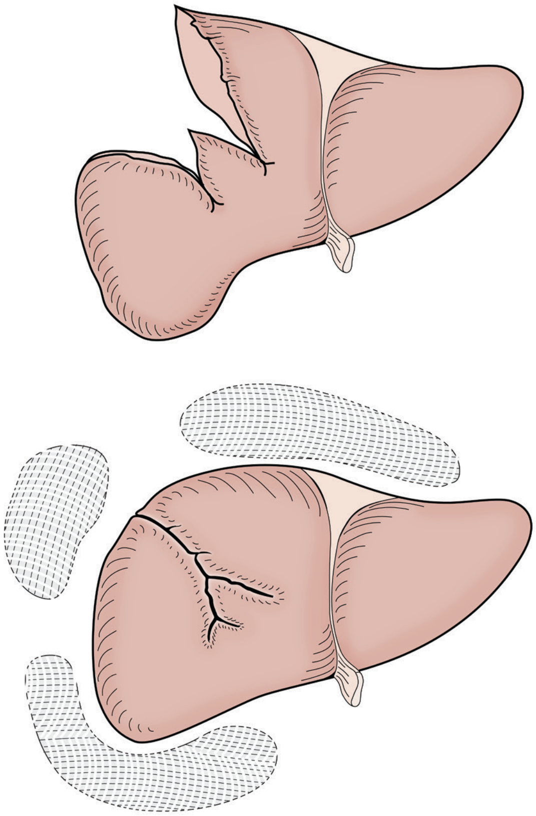

Figure 15.4 *Packs should be placed around the liver to close and compress a laceration. Packing into a laceration causes further damage.*

Major liver resection for trauma is sometimes indicated and is described in Chapter 21. It may be an anatomical resection or a resection dictated by the planes of the injury, removing only devitalised tissue and ligating bleeding vessels. Any emergency resection carries a high mortality except in expert hands, and therefore packing is now considered the first line in treatment. This may be all that is surgically required or it may be a holding measure to allow transfer of the patient to a specialised liver unit.[8]

On many occasions the surgeon has proceeded to a laparotomy because of other injuries, and a relatively minor liver injury is an additional finding. It can be very difficult to know how aggressive to be in the operative management of an injury which, if it had occurred in isolation, would have been suitable for a conservative approach. Small non-bleeding lacerations can be ignored.

Late complications of liver trauma include liver abscesses, parenchymal necrosis, bile leaks, haemobilia and arterioportal fistulae. These are discussed further in Chapter 21.

Injuries to the kidney

Blunt and penetrating injuries can both cause renal contusion and parenchymal lacerations. Most renal injuries can be managed conservatively, and useful function of even severely damaged kidneys can be regained spontaneously. A cortical laceration will form a perinephric haematoma (Figure 15.5a) and a medullary laceration will bleed into the renal pelvis with resultant haematuria (Figure 15.5b). A full-thickness laceration (Grade IV injury) will show on imaging with extravasation of contrast medium (Figure 15.5c). A non-functioning kidney suggests severe fragmentation or central renal vessel damage. Even these severe (Grade V) injuries can be treated conservatively if the patient is haemodynamically stable, as the haematoma has a tamponade effect. Angiography of a non-functioning kidney will clarify the extent of the damage further but, as the kidneys can withstand ischaemia for only 20–30 minutes, little is to be gained by exploring vascular pedicle injuries with a view to restoring renal perfusion.

Attempts to repair an injured kidney in an emergency setting are often unsuccessful, even when undertaken by an experienced urologist. A nephrectomy, which might have been avoided, becomes inevitable as the surgical exploration releases the tamponade. The treatment is therefore conservative unless an early nephrectomy is essential for severe haemorrhage with haemodynamic instability. Increasingly, even this situation can be managed with embolisation to arrest the haemorrhage, and has proved successful even in Grade V injuries.[9]

If conservative management has been chosen, the situation must be monitored, as embolisation or a delayed nephrectomy, or even an attempt at repair a few days after the injury, may be indicated if a falling haemoglobin concentration and serial CT scans prove continuing haemorrhage. Specialist urological opinion should therefore be sought early, and long-term follow-up is also essential as patients may develop secondary renal hypertension.

Surgical approach

Massive renal haemorrhage may necessitate an emergency nephrectomy. The kidney is often partially avulsed and surgery consists mainly of control of the torn renal artery and vein. An abdominal approach in trauma is therefore preferable to a loin approach, even when no associated intraperitoneal damage needs to be excluded. Vascular clamps must be available before the haematoma is entered and any remaining tamponade lost. While haemorrhage is temporarily controlled, an on-table IVU is required to check for function in the contralateral kidney if this has not been assessed preoperatively.

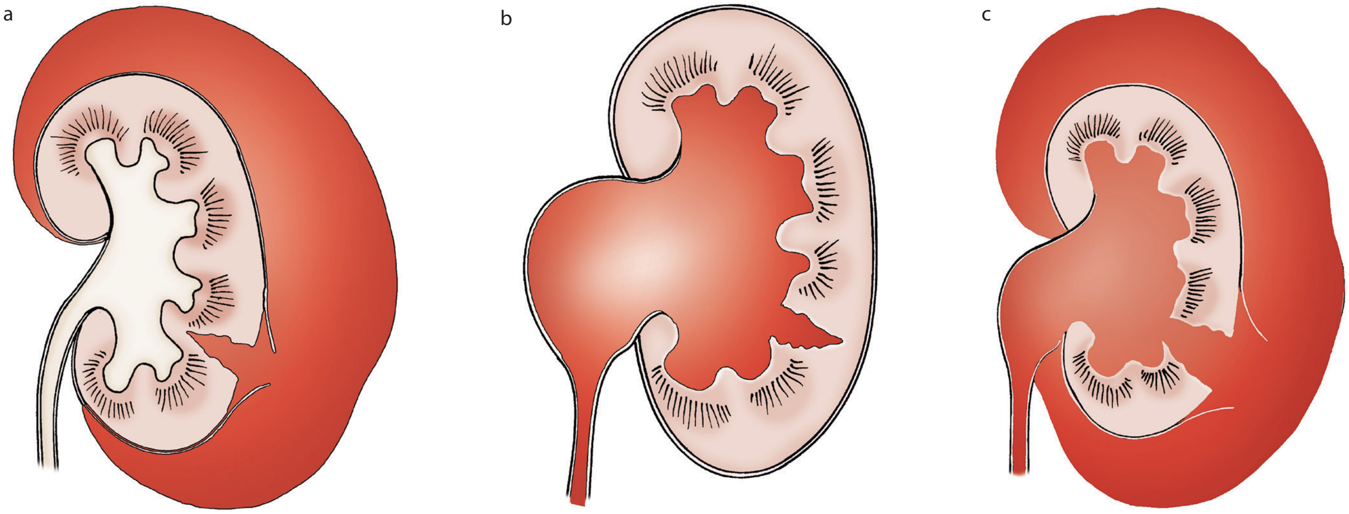

Figure 15.5 *(a) A cortical tear with the resultant perinephric haematoma, which tamponades the injury. (b) A medullary tear will lead to haematuria. (c) Gross leakage of contrast material on imaging indicates at least one full-thickness laceration, but also confirms that the kidney is still functioning.*

It may be possible to arrest continuing haemorrhage from a deep laceration or to preserve some functioning tissue with a partial nephrectomy (see Chapter 26). This can be technically challenging and a general surgeon, forced to operate on the kidney in an emergency, is more likely to have to proceed to nephrectomy. A significant renal injury in a solitary kidney therefore requires urgent specialist urological involvement, particularly if intervention appears likely.

Not infrequently, the laparotomy has been performed for another indication, and a perirenal haematoma is encountered. Exploration of this terminates the tamponade effect, and a kidney that might have regained useful function has to be removed. Unless the haematoma is actively expanding or there is massive bleeding into the peritoneal cavity, the injured kidney should be left undisturbed. This would also appear to be the case even in the management of renal gunshot wounds.

Injury to major vessels

Lacerations of the aorta and IVC require temporary vascular clamps and vascular repair. Massive pelvic haemorrhage can be reduced by ligation of the internal iliac artery on the affected side, but this is less effective than embolisation. Temporary clamps on the infrarenal aorta or on the supradiaphragmatic aorta may be valuable as a temporary measure to control haemorrhage. Other possibilities include intraluminal balloon catheters and temporary shunts. A non-expanding retroperitoneal haematoma can usually be left undisturbed, particularly if it is the result of blunt trauma, the distal flow is normal and it is not adjacent to a major artery. An expanding pulsatile haematoma requires exploration. Proximal and distal control must be secured before exploration. The surgical approaches and the repair of visceral and renal vessels, the aorta and the IVC are discussed in Chapters 6 and 7. A right or left medial visceral rotation technique should be remembered as a useful manoeuvre when access is required for an injury to the posterior aspect of the aorta or IVC.

Injuries to the stomach and small bowel

The whole small bowel and its mesentery must be inspected. Mesenteric tears should be repaired and bleeding mesenteric vessels ligated. A mesenteric laceration is the commonest cause of intraperitoneal blood if the spleen and liver are intact. A large mesenteric haematoma may require gentle evacuation and ligation of the damaged vessel. Bowel may have been devascularised by the initial laceration (see Figure 15.1), but further damage to mesenteric vessels must be avoided during evacuation of a haematoma or in the repair of a mesenteric hole. Care must be taken not to miss a posterior injury to the stomach, which will only be evident when the lesser sac is opened, or a tear at the duodenojejunal flexure, which is well recognised in deceleration injuries. Any devascularised bowel must be resected. Resection may also be advisable when there are multiple lacerations confined to one segment of the gut or when lacerations are associated with extensive bruising. Primary closure of clean holes in the small bowel or stomach with interrupted extramucosal sutures is satisfactory.

Injuries to the duodenum and pancreas

Injuries to the duodenum and pancreas may occur separately, but they are often combined injuries and may even be associated with major vessel damage. An upper midline retroperitoneal haematoma suggests significant pancreatic damage, but exploration of a contained haematoma in a stable patient is not recommended. When exploration is indicated, the need for urgent vascular control of the IVC or aorta should be anticipated and vascular clamps should be available before any haematoma is opened. Full mobilisation of the duodenum is essential before it can be adequately assessed or repaired.

Isolated duodenal injury

Many clean duodenal lacerations can simply be sutured, but more severe injuries may require complex reconstructive procedures.[10] Even after full mobilisation, repair of the second part of the duodenum is not possible if there is any significant tissue loss or contusion. A gastroenterostomy diversion, even with occlusion of the pylorus, will only divert gastric secretions. Bile and pancreatic juice will continue to enter the damaged segment. A simple, but potentially effective solution, is to insert a Foley catheter through the duodenal defect and, once a mature fistula track has been established, the catheter can be removed and spontaneous closure of the fistula anticipated. Alternatively, a Roux-en-Y loop can be brought up and sewn to the edges of the defect (Figure 15.6a). A surgical solution for severe damage to the duodenum above the ampulla is illustrated in Figure 15.6b and an option when the injury is below the ampulla is shown in Figure 15.6c. A feeding jejunostomy may be extremely useful postoperatively, and should be established at the initial emergency laparotomy.

Isolated pancreatic injury

When an isolated pancreatic injury is suspected and the pancreatic haematoma has been explored, the area of damage should be drained. However, if the main pancreatic duct has been transected, an external fistula will result. This, though, is a controlled situation in which a stable patient can be transferred at a later date to a surgeon with pancreatic expertise. However, alternatives that offer a definitive solution should be considered at the initial laparotomy in patients where there is evidence of duct transection or a high likelihood of such.[11] A distal duct transection is best treated by distal pancreatectomy, which is usually combined with a splenectomy. A severe proximal pancreatic injury – often associated with a duodenal injury – may be optimally managed by a pancreaticoduodenectomy, but this is often inappropriate at the initial exploration unless the patient is stable

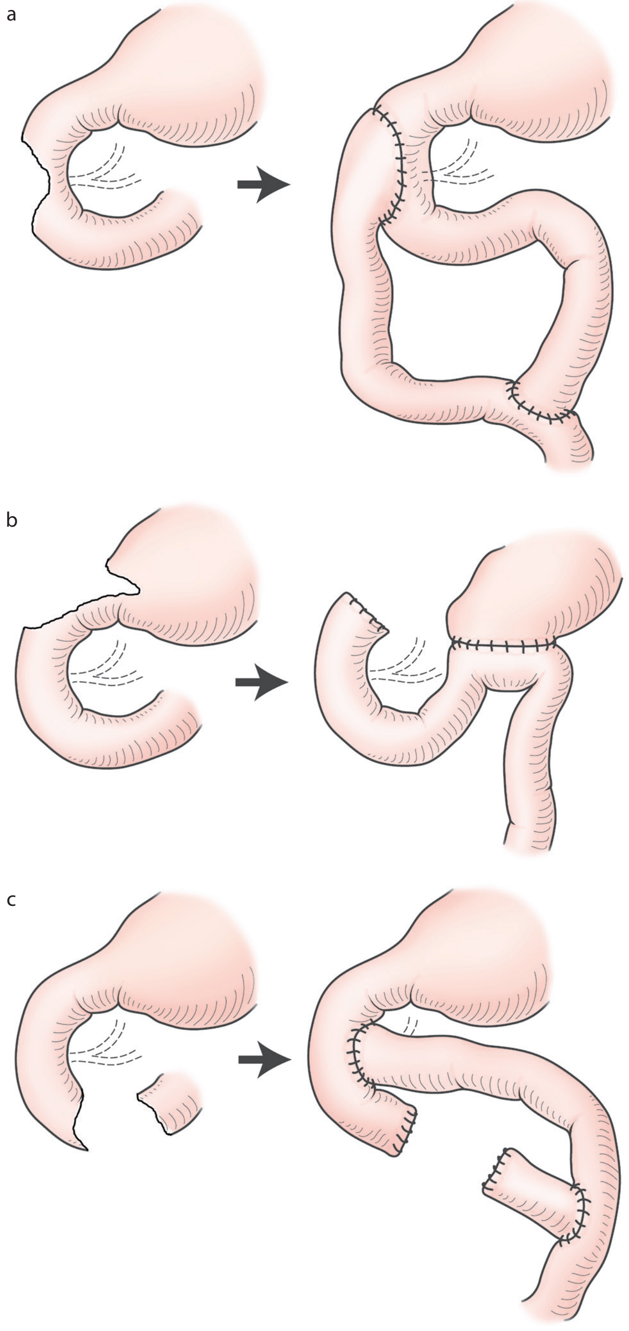

Figure 15.6 *Mobility of the duodenum is very limited and primary repair may be impossible if there is any tissue loss. (a) A Roux-en-Y loop has been brought up and anastomosed to the edges of a periampullary defect in the second part of the duodenum. (b) An injury proximal to the ampulla can be treated by antrectomy and closure of the proximal duodenum, followed by restoration of continuity with a gastroenterostomy. (c) A transection injury distal to the ampulla can be treated by closure of the ends and drainage of the duodenum by a Roux-en-Y loop.*

and the surgeon an experienced pancreatic surgeon. Damage control surgery with drains may still be preferable. Internal drainage procedures with an opened Roux loop sewn over the disrupted duct within the head of the pancreas is an alternative strategy at the initial operation, but it has found less favour recently in major trauma centres. Fortunately, many pancreatic blunt injuries occur in isolation and the diagnosis is delayed. The most common such injury is a pancreatic transection over the convexity of the vertebral bodies. The diagnosis may be suspected clinically, and a rise in the blood amylase level supports the clinical diagnosis. A delayed CT scan, performed a few days after the injury, confirms the diagnosis. It is then possible to transfer such patients to an experienced pancreatic surgeon. Pancreatic operations are described in Chapter 20.

Combined injuries

Patients with a very severe injury to the pancreatic head and duodenum occasionally require a pancreaticoduodenectomy, but in an emergency this carries a high mortality even in expert hands. A Roux loop for drainage of the pancreas combined with diversion of gastric secretions away from the duodenum is a safer alternative. Severe pancreaticoduodenal injury may be associated with additional damage to the bile ducts, portal vein or mesenteric root, and survival from such injuries is unlikely.

Injuries to the colon

Colonic injury may be immediately apparent on opening the peritoneum. It is important to remember that a penetrating wound or a rupture of the colon from a blunt injury may also occur retroperitoneally, where the consequences of faecal contamination are equally devastating. If there is any likelihood of this, the colon must be fully mobilised and inspected. Traditional military teaching was that all colonic injuries should be exteriorised and primary repair not attempted.[12] However, this is no longer considered necessary and primary repair, whether by a sutured closure or a resection with primary anastomosis, is now recommended. It has been shown to be safe even in unfavourable circumstances,[13] but some caution should remain regarding left-sided colonic trauma. The peritoneal cavity is cleaned of all contaminants and washed with saline or an antibiotic wash. Broad-spectrum systemic antibiotics are given and continued postoperatively. On-table colonic lavage (see Figure 23.4, p. 417) may reduce the risk of anastomotic leakage, and the advisability of a temporary proximal loop stoma should be considered if the surgeon has any concern over an anastomosis or a sutured laceration in the large bowel (see Chapters 22 and 23).

Injuries to the rectum

The rectum may be injured in a major crushing injury of the pelvis. Damage more often occurs from penetrating lower abdominal injuries or from perineal impalement. In the latter, the direction and depth of impalement will determine whether the rectal injury is retroperitoneal or intraperitoneal, and also whether any additional damage has been sustained to the bladder, membranous urethra or intra-abdominal structures. When there are signs of peritonitis after a perineal impalement, a laparotomy or laparoscopy should be performed to exclude an intraperitoneal rectal injury or additional injuries to the bladder or to loops of small bowel. Otherwise, a perineal wound can be explored initially from below, with the patient in the prone jack-knife position. It may prove to be only a superficial track or a rectal injury may be identified or suspected.

The traditional management of a proven or suspected retroperitoneal rectal injury has been rectal mobilisation from the abdomen and repair of any laceration found, followed by drainage of the retrorectal space and a defunctioning colostomy, combined with a distal rectal washout. Although this should probably remain the gold standard for severe injuries, including high-velocity gunshot wounds, a less aggressive approach has been shown to be a safe alternative in a large series of low-velocity injuries in South Africa.[14] A laparoscopy was performed to exclude intraperitoneal injury and also to raise a loop colostomy, without any attempt to explore or repair the retroperitoneal injury or to drain the retrorectal space.

Injuries to the bladder

An intraperitoneal bladder tear is sutured in two layers with absorbable material and a urethral catheter left *in situ* on free drainage for 10 days. Extraperitoneal bladder tears and urethral injuries are discussed further in Chapters 25 and 26.

Injuries to the diaphragm

Rupture of the diaphragm can occur with blunt trauma. Penetrating injuries to the abdomen or chest may also lacerate the diaphragm, and the incidence may be as high as 15 per cent in lower chest stab wounds. The injury is easily missed, and presentation may be years later in a patient who never came to surgery at the time of trauma. When an emergency laparotomy for trauma is undertaken, the diaphragm should be checked and any laceration carefully sutured (see also Chapter 8).

Massive intra-abdominal trauma

Occasionally, an immediate laparotomy is necessary in parallel with intensive resuscitation, and the surgeon is faced with exsanguinating haemorrhage, widespread massive injury and gross peritoneal soiling. In addition, there may be retroperitoneal and mesenteric haematomata of doubtful significance. The patient is probably hypothermic, acidotic and coagulopathic. Once active haemorrhage is controlled, a temporary solution is prudent. Gastrointestinal contents are cleared from the peritoneal cavity and any areas of damaged leaking gut simply isolated with stapling instrument division or sutures. The abdominal wall fascia is left open, but the skin is closed if this is possible. If the tension is too great because haematoma or liver packs, a temporary containment should be used (see Chapter 13). The patient is transferred to intensive care with the intention of performing definitive surgery in 6 to 48 hours when his or her general condition has improved.[15] Imaging will be difficult to perform during this period but, from the initial laparotomy, problems will be anticipated for which the assistance of a particular specialist might be needed.

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16

SURGERY OF INTRA-ABDOMINAL MALIGNANCY

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The surgery of intra-abdominal malignancy forms a large proportion of the workload of a gastrointestinal surgeon. Almost without exception, the only single intervention that can offer a patient the chance of a cure is a well-performed operative resection, with the addition of neoadjuvant (preoperative) radiotherapy and/or chemotherapy in selected cases. However, the need for a laparotomy to establish whether potentially curative surgery is possible has diminished with improvements in preoperative imaging, and palliative intervention is now shared with radiologists, radiotherapists and oncologists. When a curative resection is possible, it is of the utmost importance that a surgeon does not jeopardise the possibility of cure by inadequate or poorly planned surgery. When cure is no longer possible, radical surgery sometimes still offers the best palliation, but the surgeon must avoid inappropriate radical surgery. A simpler operative procedure may be as effective in relieving symptoms, and in other situations surgery may have no place. Surgeons must understand the methods of spread, and the natural history of, the various intra-abdominal malignancies if they are to make the best operative decisions.

ADENOCARCINOMA OF THE GASTROINTESTINAL TRACT

Adenocarcinoma is the commonest intra-abdominal malignancy. The mode of tumour spread, and therefore the principles underlying a radical resection, are similar throughout the gastrointestinal tract. However, the various modes of spread show regional variation along the gastrointestinal tract, and this influences the surgical strategy.

SUBMUCOSAL EXTENSION

Submucosal extension of malignant cells beyond the macroscopic edge of a tumour has long been recognised[1] and is a major problem in upper gastrointestinal tract tumours. In oesophageal cancer, involved resection margins are not uncommon even with a macroscopic clearance of 5 cm. Multifocal field change is another problem in oesophageal malignancy and it may be difficult to differentiate from submucosal spread (Figure 16.1). In colonic cancer, early research also suggested significant intramural extension and concern continued as to whether preservation of the anus in a mid-rectal cancer was oncologically sound until it was shown that the macroscopically normal mucosa a few millimetres beyond a tumour was almost invariably free of malignant cells.[2]

DIRECT INVASION

Direct invasion by a tumour to involve adjacent structures is classified as a locally advanced (T4) tumour, but this is not always associated with metastatic spread. There may be no lymphatic or blood-borne metastases, and cure by radical surgery is still possible. Preoperative radiotherapy improves the chance of a curative resection in some T4 rectal cancers (see Chapter 23). The tumour must not be 'ruptured' at operation, and therefore any involved structures must be removed *en bloc* (Figure 16.2). For instance, the rectum can be excised with a seminal vesicle or a cuff of vagina. A colonic tumour can be excised with an adherent disc of anterior abdominal wall, the dome of the bladder or a loop of small bowel. This is more often appropriate in lower rather than in upper gastrointestinal tract tumours. In the upper gastrointestinal

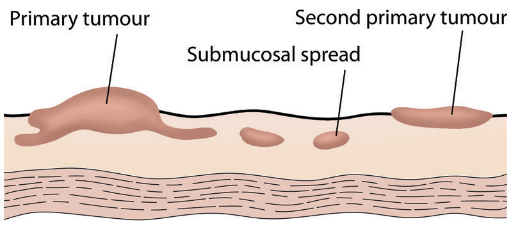

Figure 16.1 *Some carcinomas spread along the submucosal plane. Multifocal primary tumours can also arise within areas of premalignant field change. In both situations a wide clearance of the macroscopic primary tumour is necessary to ensure tumour-free resection margins.*

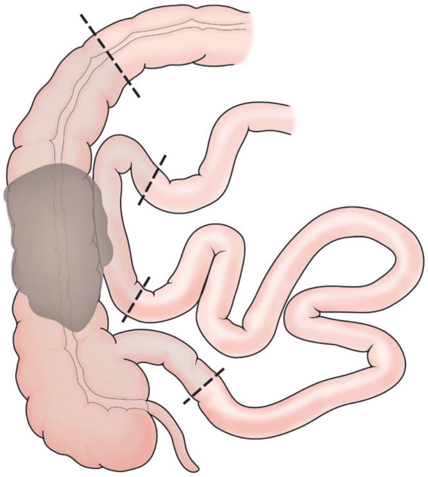

Figure 16.2 *A radical resection of this ascending colon cancer requires an* en bloc *excision of the adherent loop of small bowel with the primary tumour. An additional small bowel anastomosis will be required.*

tract a locally advanced tumour is rare in the absence of dissemination.

It is often difficult at operation to distinguish between malignant infiltration by a tumour and an inflammatory adhesive reaction to a tumour. Differentiation can only be made on histological examination, and the surgeon therefore has no option but to assume that the adhesion represents malignant infiltration if curative surgery is to be attempted. This will, however, be an inflammatory adhesion, with desmoplastic fibrosis, in around 50 per cent of such cases.

Direct invasion along perineural planes is now recognised as a separate phenomenon from lymphatic spread. It is seen particularly in pancreaticobiliary tumours, and carries a poor prognosis.[3]

Metastases

In order for metastases to be established, viable tumour cells must be shed from the tumour and transported to a new host site, where they must then be able to establish their own microcirculation. The ability of shed cells to implant at new sites is very variable. Cells may be taken into the lymphatic system or they may form tumour emboli within blood vessels. In addition, cells may be released from the surface of a tumour into the gut lumen or into the peritoneal cavity. Shedding of viable tumour cells occurs spontaneously, but it may also occur during surgery, especially if the dissection enters the primary tumour or transects the lymphatic drainage channels. This 'infective' capacity of tumour cells has long been recognised.[4]

TUMOUR SPILLAGE

Intraluminal spread

Intraluminal seeding of tumour cells has been reported in haemorrhoidal wounds in the presence of a colorectal carcinoma.[5] It has also been shown to occur from an oesophageal tumour to the anterior abdominal wall around the placement of a gastrostomy tube.[6] The anastomotic suture line recurrences in colorectal cancer surgery reflect both this phenomenon and the ingrowth of inadequately excised lymph node disease. Intraluminal cytotoxic washes are used perioperatively to prevent intraluminal seeding.

Transcoelomic spread

This is a frequent mode of spread in gastric cancer, but is less frequent in colonic cancer. It can occur in any cancer that has breached the serosa and then sheds cells intraperitoneally. Viable tumour cells may also be spilled at the time of surgery from intraluminal spillage, tumour rupture during dissection or transection of involved lymphatic channels. Meticulous surgical technique is therefore important and can be combined with tumouricidal peritoneal washes. Even washes with water will cause osmotic disruption and cell death. Serosal seeding may occur on any peritoneal surface, but the ovary is a particularly fertile site for implantation. Early experience with laparoscopic resections for malignancy revealed an unacceptably high port site recurrence rate, even after potentially curative operations.[7] Protection of the wound during retrieval of the specimen had already been addressed and it was realised that the problem was probably a reflection of general peritoneal malignant contamination from tumour rupture or lymphatic transection during the dissection. Laparoscopic colorectal surgery for malignancy was temporarily halted in the UK, outside of clinical trials, until it could be demonstrated that there was no difference in long-term survival between the open and laparoscopic approaches. In skilled hands, the laparoscopic dissection for most intra-abdominal cancers can now be performed to the same standard as in an open operation and port site metastases are now a rarity. This early experience did, however, highlight that any compromise in the dissection of a malignancy is likely to outweigh any short-term benefit from a minimal-access operation.

Macroscopic seedlings at the time of surgery virtually preclude a curative resection. In upper gastrointestinal malignancy, where other modalities often offer better palliation than surgery, metastases should, if possible, be diagnosed preoperatively. Small peritoneal deposits are not easily detected by CT scans or other imaging, and a laparoscopy before resectional surgery may avoid an unnecessary laparotomy.

The fear of *microscopic peritoneal deposits* has encouraged surgeons to consider a role for prophylactic intraperitoneal chemotherapy at the time of an apparently curative resection in selected cases. Although results from Japan have been encouraging, the practice has not been widely adopted.[8]

LYMPHATIC SPREAD

Metastases occur in the mesenteric lymph nodes of the gut via the lymphatic drainage channels of the tumour. Lymphatic drainage follows the arterial vascular system (Figures 16.3 and 16.4) and metastases usually occur in an orderly pattern, with involvement first of the nodes adjacent to the organ, followed by those close to the roots of the three visceral arteries, and finally in the preaortic nodes. All radical carcinoma surgery aims to remove the lymphatic drainage of a tumour *en bloc* with the tumour itself. Even if the nodes are macroscopically normal, they may contain microscopic deposits. *En bloc* resection is important, as dissection across lymphatic channels may spill viable tumour cells into the peritoneal cavity. The radicality of lymph node resection varies, and the decision is difficult when increased radicality is known to result in higher operative morbidity or mortality, especially in tumours where the surgeon is aware that in most patients greater radicality is either unnecessary or fruitless.

Gastric cancer metastasises to the lymph nodes along the four gastric arteries, and then to the preaortic nodes. The lymphatic drainage has been extensively mapped and the nodes divided into separate groups (Figure 16.5). The traditional radical gastrectomy did not include all these groups of lymph nodes, and a more radical lymphadenectomy was only carried out for clinically involved nodes, in situations where it was already too late to attempt a cure. However, it is now known that in the absence of liver secondaries, peritoneal seedling or preaortic enlarged nodes, cure rates can be increased by a more radical lymphadenectomy, in which clinically normal nodes are removed. Unfortunately, this more extensive surgery can be associated with a higher perioperative mortality. Early mucosal T1-stage cancers diagnosed on endoscopy pose further problems. In those in which lymph node metastases are very unlikely, a local excision either without lymphadenectomy or with only excision of the nodes adjacent to the stomach wall close to the tumour may be all that is required. These issues are discussed further in Chapters 17 and 18.

Oesophageal cancer drains to cervical and coeliac nodes in addition to thoracic nodes. Radical resections include the dissection and *en bloc* excision of these drainage nodes. There is, however, no containing mesentery and no apparent 'tumour package'. Local extension and distant metastases also occur early.

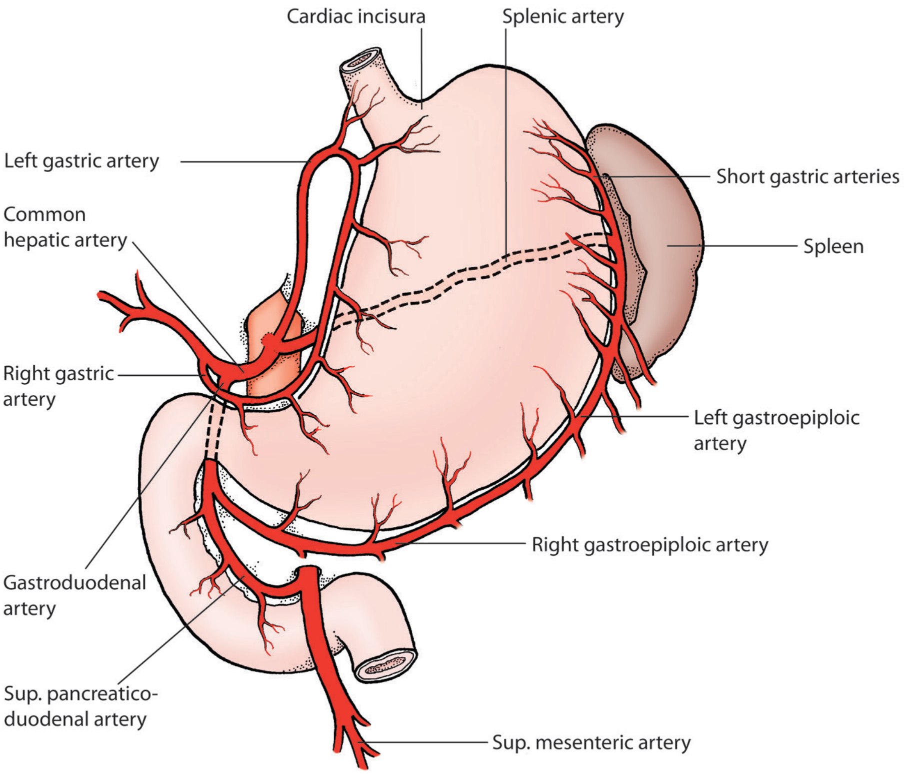

Figure 16.3 *The arterial anatomy of the stomach. The lymphatic drainage channels follow the arteries (see Figure 16.5).*

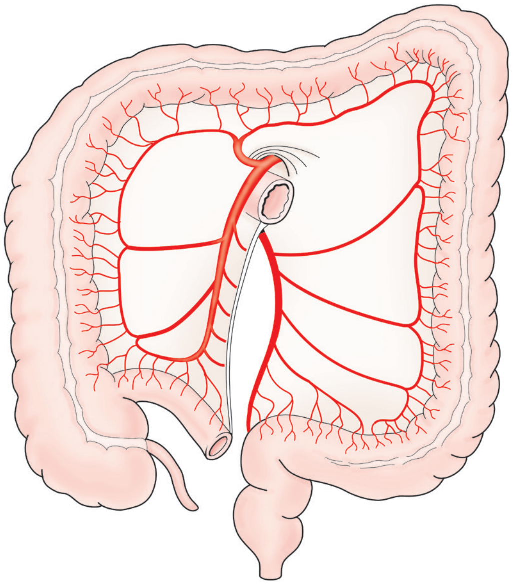

Figure 16.4 *The lymphatic drainage of the colon follows the arteries. A radical lymphadenectomy can therefore be planned on the basis of the arterial anatomy. The arterial division then dictates the length of bowel that will have to be excised.*

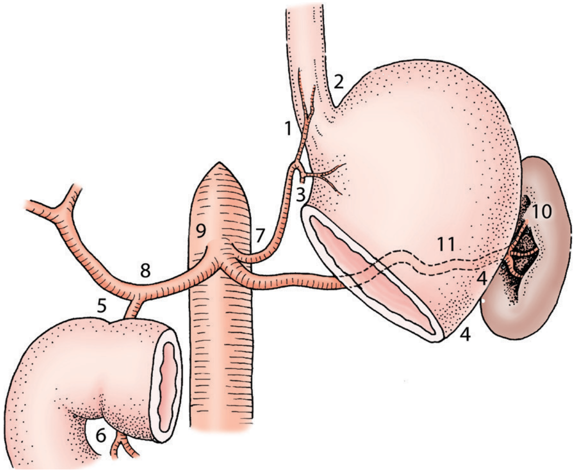

Figure 16.5 *Gastric lymph nodes have been mapped and numbered. Nodes 1–6 are in the greater and lesser omentum, adjacent to the stomach wall, alongside the arterial arcades. Nodes 7–11 are along the more proximal course of the gastric and gastroepiploic arteries, which are now retroperitoneal in position. Nodes 12–16, which are not shown in this diagram, lie either outside the main lymphatic drainage pathways of the stomach or in the pathway but proximal to the coeliac root.*

Pancreatic cancer drains directly to retroperitoneal nodes, but this tumour also metastasises early both to the liver and within the peritoneal cavity. These metastases and direct extension into the portal vein or mesenteric vessels are usually more important limiting factors to a radical curative resection than lymph node metastases.

Primary liver tumours spread by infiltration along planes within the liver, and lymphatic spread is not a major consideration.

In *rectal and colonic cancer*, decisions regarding the radicality of the lymphadenectomy are more straightforward, as removal of the whole of the mesenteric drainage area as far as the mesenteric root adds little to the morbidity (Figure 16.4). The removal of preaortic nodes is usually considered fruitless if they are involved – and pointless if they are not – although it is still possible that there could be a marginal gain in patients with only microscopic involvement.

Squamous cell carcinoma of the anal canal drains to the inguinal nodes, in addition to some drainage to the nodes along the inferior mesenteric artery. Treatment of this malignancy is no longer primarily surgical, with excellent results in most cases by combinations of radiotherapy and chemotherapy (see Chapter 24).

HAEMATOGENOUS SPREAD

Portal vein dissemination

The portal vein is the main route for haematogenous spread of all gastrointestinal carcinomas within the portal venous drainage system. (The intrathoracic oesophagus and anal canal also drain directly into the systemic system.) Extramural invasion of veins by tumour is sometimes reported by the pathologist and this, in general, is an indicator of a poor prognosis. Primary and secondary tumours in the liver can invade branches of the portal vein and spread to other sites within the liver by this route.

Secondary deposits in the liver can occur early in the growth of a carcinoma, and many patients with an apparently normal liver at the time of surgery are shown subsequently to have already had micrometastases. This was the basis of an early trial with adjuvant perioperative portal vein chemotherapy. Even if perioperative chemotherapy is to be considered, this technique has now been abandoned as it compared unfavourably with perioperative peripheral intravenous chemotherapy.[9]

Patterns of liver metastases vary among different tumours. Multiple tiny seedlings throughout the liver are clearly unsuitable for surgical removal. Colonic tumours often produce only a few secondaries in the liver and surgical excision, if technically feasible, should always be considered as cure is still possible. Although this has been known for some years,[10] there is now an increasing percentage of patients who are suitable for curative liver resections (see Chapter 21).

Systemic blood-borne dissemination

Systemic metastases most often occur as part of a generalised dissemination of tumour in a patient who already has intraperitoneal, retroperitoneal and liver secondaries. Isolated secondaries do, however, occur in such sites as the brain and lungs and may be suitable for resection with curative or palliative intent.

CARCINOID TUMOURS

Carcinoid (neuroendocrine) tumours arise from the enterochromaffin cells, which are present throughout the gastrointestinal tract and may be either benign or malignant. A small benign carcinoid is most often encountered in an appendix that has been removed because of appendicitis. The tumour, rather than a faecolith, has obstructed the lumen and initiated the appendicitis. A small bowel carcinoid may cause obstructive symptoms, and at surgery will be excised as a possible small bowel carcinoma. These tumours are frequently multiple and the whole small bowel must be carefully examined. Malignant carcinoid tumours have a pattern of spread similar to that of gastrointestinal carcinomas, but they are slower growing and a patient with metastatic carcinoid may remain in reasonable health for some years. Carcinoid tumours secrete 5-hydroxytryptamine (5HT) (serotonin) and other related active compounds, which are metabolised in the liver. When the systemic levels of these active compounds rise and the symptoms of '*carcinoid syndrome*' develop, it indicates that the tumour is draining directly into the systemic circulation. Thus, it usually indicates liver metastases draining into the hepatic veins, but the liver can also be bypassed when there are tumour deposits in the retroperitoneal nodes. The flushing, diarrhoea and bronchoconstriction of the carcinoid syndrome can be controlled with octreotide (which blocks 5HT release), but resection of liver secondaries should also be considered, especially as this is one of the few situations where even partial removal of liver secondaries may lead to a significant improvement in symptoms and prognosis.[11]

HORMONE-PRODUCING INTRA-ABDOMINAL TUMOURS

This group includes all the relatively rare tumours that present almost exclusively as a result of their biochemical activity, and the physiological effects that they engender. They are often only a few centimetres in diameter, frequently multiple and may be either benign or malignant. Many patients have a familial endocrine disorder. The diagnosis and localisation of these tumours has become increasingly sophisticated and outwith the scope of an operative general surgical textbook.[12] Insulinomas and gastrinomas may require pancreatic resection and adrenal tumours an adrenalectomy (see Chapter 20).

PSEUDOMYXOMA PERITONEI

Pseudomyxoma peritonei is a rare tumour presenting as mucinous ascites secondary to a peritoneal surface malignancy, and the mucinous ascites may fill the peritoneal cavity. The visceral and parietal peritoneal surfaces have adherent tumour consisting of cysts of trapped jelly, and tumour masses form in the omentum, around the spleen and in the pelvis. Classical pseudomyxoma is a mucinous adenoma or low-grade mucus-producing adenocarcinoma, which is at best described as a 'borderline malignancy' on the peritoneal surface, but otherwise it does not have the ability to metastasise. The commonest site of origin is from an adenoma of the appendix, and it is only after rupture that peritoneal dissemination occurs.[13] In women, many cases are incorrectly classified as ovarian cancers as large deposits grow on the ovaries, and there can also be confusion with frankly malignant mucinous adenocarcinomas of the colon. Worthwhile long-term palliation, and even cure, is possible with an extensive peritonectomy and intraperitoneal chemotherapy.

The surgery is specialised and involves a radical omentectomy, inside the gastroepiploic arcade, and extensive stripping of involved parietal and visceral peritoneum by diathermy dissection, combined with the excision, if necessary, of extensively encased organs such as spleen, gallbladder, stomach and segments of colon. Fortunately, the small bowel and its mesentery is relatively spared. Specialised centres have been established for the surgical management of these tumours, and referral is indicated. If this tumour is suspected at laparotomy, histology should be obtained, preferably by an omental biopsy. Any partial debulking procedure or hysterectomy should be avoided as the tumour will seed onto any raw, non-peritonealised surfaces exposed by the surgery. The resultant encasement of vital structures, such as ureters, makes subsequent complete cytoreduction more hazardous. Primary peritoneal mesothelioma poses similar surgical challenges, but the prognosis is worse.

INTRA-ABDOMINAL SARCOMAS

Gastrointestinal stromal tumours

Gastrointestinal stromal tumours (GISTs) are mesenchymal tumours that can occur throughout the gastrointestinal tract; they were previously classified as leiomyomas and leiomyosarcomas. Presentation is often with gastrointestinal haemorrhage or an acute abdominal emergency[14] and the diagnosis may only be made at emergency laparotomy. The clinical behaviour of GISTs is very varied, but they should all be regarded as potentially malignant. In common with other sarcomas, they recur locally if the margins of excision have been inadequate. GISTs metastasise via the bloodstream but, as lymphatic spread is not an issue, surgery is focused on wide local excision rather than lymphadenectomy. Chemotherapy has little to offer and radiotherapy can seldom be deployed without unacceptable toxicity at dosages that might be curative. An increased understanding of their origins, probably from pacemaker cells of the gut, has led to the development of the tyrosine kinase inhibitor imatinib (Glivec®) as an effective treatment for irresectable disease.

Retroperitoneal sarcomas

Retroperitoneal sarcomas are generally more aggressively malignant than GISTs. They present late as there is no early gastrointestinal obstruction or haemorrhage. Surgical excision is often combined with radiotherapy, which can be focused to give adequate doses to the tumour while avoiding excessive exposure to the small bowel.

Desmoids

Desmoid tumours are a borderline malignant soft tissue tumour that can occur both in the abdominal wall and intra-abdominally. They are common in patients with familial adenomatous polyposis. Desmoid tumours do not metastasise but are locally aggressive, with a propensity for recurrence after resection. The more common abdominal wall tumours are seldom life threatening, but the intra-abdominal lesions, which are most often located within the mesentery, may cause small bowel complications. Management decisions are difficult, as the proximity of the tumours to mesenteric vessels renders surgical excision technically difficult, with a high morbidity and mortality.[15] The natural history of the lesion, if left *in situ*, is very variable and may be modified by the administration of tamoxifen, non-steroidal anti-inflammatory agents or cytotoxic chemotherapy. These tumours are best managed in specialised centres.

LYMPHOMA

A lymphoma can occur within any mesenteric or retroperitoneal lymph node. In addition, a lymphoma can arise from the lymphoid tissue in the gut wall, classically producing a thickened area of small bowel, which may ulcerate or obstruct. A lymphoma may also form the apex of an intussusception. Although the definitive treatment is medical, the initial surgical presentation with a mechanical complication, haemorrhage or inflammation often necessitates a resection, which also provides the tissue for histological diagnosis.

UROLOGICAL MALIGNANCY

The treatment of urological malignancies is discussed briefly in Chapter 26. Hypernephroma is the commonest renal tumour and should be considered preoperatively in the differential diagnosis of an intra-abdominal mass. Malignant spread is both by local extension and haematogenous metastasis. Local extension into the peritoneum is uncommon. Carcinoma of the prostate and bladder seldom cause generalised intra-abdominal problems, and symptoms are commonly restricted to the urological system. Most patients with advanced disease die either from uraemia caused by ureteric obstruction or from distant metastases. However, a locally aggressive urological malignancy can produce a similarly appalling fistulous situation in the pelvis, as can a rectal carcinoma that has invaded the prostate or bladder. If careful assessment indicates a tumour that has not metastasised, a radical pelvic exenteration with faecal and urinary stomas may be indicated. More often, only palliation of the obstruction or of the rectovesical fistula is possible. A colostomy to divert the faecal stream improves the urinary symptoms considerably. Radiotherapy may offer additional palliation to patients with a longer life expectancy.

GYNAECOLOGICAL MALIGNANCY

Carcinoma of the cervix and the body of the uterus usually only involves general surgeons when an extensive pelvic clearance is planned for a locally advanced tumour. Ovarian carcinoma, in contrast, produces an intraperitoneal mass to which bowel can adhere. It also spreads transcoelomically to form deposits throughout the peritoneal cavity. These deposits result in an omental 'cake' of tumour and malignant adhesions between loops of bowel, and the patient may present with a small bowel obstruction, ascites or an intra-abdominal mass. Surgical treatment is discussed further in Chapter 27, but the surgery is again influenced by the behaviour of the tumour. In contrast to most other widespread intra-abdominal malignancies, good palliation can be achieved with chemotherapy. This is more effective if the tumour burden has been reduced, and therefore a debulking procedure should be attempted. Gynaecologists generally recommend a total hysterectomy with bilateral salpingo-oophorectomy and an infracolic omentectomy.

It must also be remembered that an ovarian mass and extensive intraperitoneal deposits are not diagnostic of ovarian malignancy. Any tumour cells that have seeded transcoelomically will thrive on the surface of the well-vascularised ovary and may be encountered in the absence of other macroscopic intraperitoneal deposits. Large, and often bilateral, secondary tumour masses in the ovary associated with gastric cancer were first described by Krukenberg in 1896. Tumour cells can also reach the ovary through the bloodstream and similar, apparently isolated, ovarian secondaries are occasionally seen in metastatic breast carcinoma. It is the routine practice of some surgeons to remove the ovaries prophylactically during the course of any laparotomy for malignancy in a post-menopausal woman. This will avoid the possible necessity for a later operation for a symptomatic ovarian secondary, but it is unlikely that many additional cures will be achieved by this policy. A bilateral oophorectomy will also protect the patient from a primary ovarian cancer in the future, and an argument could therefore be made for routinely removing post-menopausal ovaries at any laparotomy. Patient attitudes to this are very varied, and preoperative discussion and consent are imperative.

PELVIC NODE MALIGNANCY

Presentation may be with iliac fossa pain or a palpable mass. Alternatively, encasement of the common iliac vein, with resultant obstruction from compression or distortion, will cause lower limb swelling from venous obstruction. The inguinal nodes, draining the lower limb and perineum, are continuous with the external iliac chain at the ilioinguinal ligament. The internal iliac nodes drain the prostate, bladder and uterus (Figure 16.6). A malignant mass of iliac nodes may represent a primary lymphoma or it may be the presentation of an occult malignancy within the drainage area. Malignant melanomas and prostatic carcinomas are probably the most likely cancers to present in this way, although lymph node metastases in this site may occur with any intra-abdominal or pelvic malignancy. Occasionally, no primary lesion can be identified, a lymphoma is suspected and a tissue diagnosis is required. A CT-guided biopsy will be sufficient to diagnose a secondary malignancy, but the core of tissue obtained is usually inadequate to confirm a lymphoma or to differentiate between the different varieties. A surgical biopsy is then requested and is ideally performed by a laparoscopic approach. An open biopsy is via a left iliac fossa muscle-cutting incision, staying extraperitoneal and sweeping the peritoneum medially. Great care must be taken as the matted nodes lie in close proximity to the iliac vessels, and the anatomy may be both obscured and distorted.

A *radical lymphadenectomy* of the pelvic nodes may be performed as part of a potentially curative resection for urological, testicular or gynaecological malignancy. In rectal cancer, spread to these nodes is an indication of advanced disease and little is gained by radical excision. The iliac nodes, as an extension of the inguinal chain, are sometimes excised as part of a radical groin dissection for melanoma or penile cancer, and inguinal lymphadenectomy is described in Chapter 25. Palliative excision of symptomatic nodal involvement is seldom indicated or, indeed, possible. Radiotherapy or chemotherapy may be appropriate, depending on the primary pathology, and consideration should be given to the possibility of relieving venous obstruction by intraluminal vascular stenting.

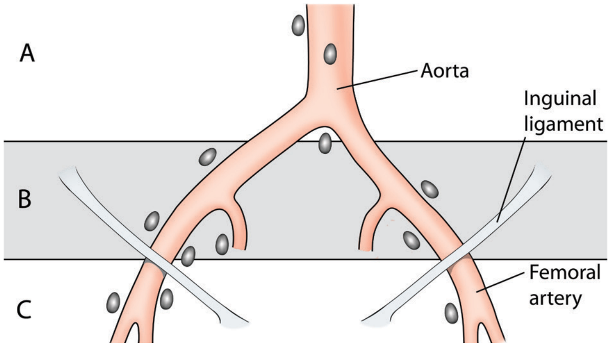

Figure 16.6 *The para-aortic nodes (A) drain the two iliac chains (B). The uterus, prostate and bladder drain to the internal iliac nodes. The external iliac nodes are an extension of the inguinal chain (C), which drains the lower limb and perineum.*

PREOPERATIVE INVESTIGATION AND STAGING OF TUMOURS

Diagnosis of a tumour, and the potential for a curative resection, can now often be established before surgery. Management decisions can be taken preoperatively, and in advanced malignancy both surgical and alternative palliative measures considered. For surgeons who are working in hospitals with limited access to sophisticated imaging, a laparotomy may still be the only means of establishing the resectability of a tumour. When a curative resection is not possible and surgery already undertaken, a palliative resection or surgical bypass can then be offered.

Carcinomas of the oesophagus, stomach and pancreas metastasise early, and life expectancy with metastatic disease is short. Endoscopic stenting of the oesophagus, pylorus or common bile duct have proved to be comparable with, or superior to, surgical bypass or palliative resection in most situations. Control of the local obstructive symptoms is maintained until the patient dies of distant metastases. Preoperative assessment of upper gastrointestinal or hepatobiliary malignancy is therefore very important, as unnecessary laparotomies can be avoided. However, temporary preoperative stenting of a potentially curative malignancy of the biliary system should be avoided as it will commonly introduce infection.

In colorectal cancer, colonic stenting can be used to relieve obstruction and is an excellent palliative measure when life expectancy is short and the risk of a major operation high. However, other patients with known metastatic disease may still be better served by resection of the primary lesion. If the primary tumour is left *in situ*, luminal loss of blood and mucus will continue, involved adherent bowel loops may obstruct and rectal cancer has the potential to invade the bladder or pelvic side wall nerves with severe symptoms.

Preoperative sophisticated imaging, which can accurately stage a malignancy, has enabled a more coordinated, multimodality approach to be taken to cancer treatment. Preoperative radiotherapy, chemotherapy or chemoradiotherapy is increasingly used to 'downsize' and 'down-stage' tumours before surgery. Surgery may then be delayed for several months to obtain the maximum benefit from this treatment, and repeat imaging can monitor the response. Some locally advanced malignancies become resectable and potentially curable with this approach, which has been employed most frequently in oesophageal and rectal cancer and also for initially inoperable liver secondaries.

INTRAOPERATIVE DILEMMAS IN ABDOMINAL MALIGNANCY

The acute abdomen and curable malignancy

Many malignancies present as an acute problem, and surgery may have been performed as an emergency for obstruction, perforation or haemorrhage arising as a complication of the tumour. Alternatively, the inflammation around a tumour may have been misinterpreted as a minor benign condition such as an appendicitis. If a potentially curative radical resection is possible, it should ideally be undertaken at this operation. If this is not appropriate owing to the patient's poor general state, the surgeon's inexperience or other factors, it is important that the emergency surgery does not jeopardise the possibility of subsequent cure. A temporary solution such as a defunctioning stoma may be sufficient to treat the emergency presentation, and definitive surgery can be performed under more ideal circumstances at a later date.

Inoperable malignancy

When, at operation either in an emergency or an elective setting, an incurable malignancy is encountered, the surgeon must first decide if any operative procedure will offer palliation. An estimation of the patient's life expectancy and the quality of remaining life will be as valuable in this decision as an assessment of surgical feasibility. Resection of an obstructing primary tumour may still be the best palliative option, but alternatives such as bypass should be considered. The additional distress of a stoma during the final few months of life should be avoided if there is any alternative. A gastrostomy, however, may save the patient from prolonged nasogastric tube drainage, and should be considered. Occasionally, no useful surgical procedure is possible. There may be multiple levels of obstruction from intraperitoneal malignant dissemination. The risk of anastomotic dehiscence is increased in advanced malignancy, and the risk of enterocutaneous fistulae should temper surgical overenthusiasm in this situation.

Tumour biopsy for histology is important, and an omental deposit is often the easiest to excise. A diagnosis of carcinoid, lymphoma, metastatic breast or gynaecological cancer, or even pseudomyxoma, will radically change both the management and the prognosis. It must also be remembered that not all liver secondaries are incurable and the biopsy of liver metastases can result in needle tract seeding and should be avoided.[16]

Probable, but unconfirmed, malignant pathology

Even in elective surgery there may be no absolute proof of malignancy, despite a high level of suspicion and extensive preoperative investigations. In this situation the surgeon will have to proceed to a radical dissection to avoid an oncologically inadequate operation, but in the knowledge that in perhaps 30 per cent of cases the final histology will prove to be benign and the extent of the surgery unnecessarily radical. Circumscribed pancreatic cancers can be difficult to differentiate from benign lesions, and a hilar cholangiocarcinoma may be indistinguishable from sclerosing cholangitis. The differentiation of sigmoid cancer from diverticular disease can pose similar difficulty.

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17

CLASSIC OPERATIONS ON THE UPPER GASTROINTESTINAL TRACT

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The focus in upper gastrointestinal surgery has changed greatly as advances in pharmacology, interventional endoscopy and radiology have led to the loss of many operations from the routine practice of most surgeons. In contrast, advances in minimal-access techniques have led to surgery being a better alternative to conservative management for some other conditions. Improvements in anaesthesia and critical care have also had an impact, as they have made more major procedures possible with an acceptable mortality and morbidity.

Some classic operations described in this chapter are no longer commonly performed, but are included as surgeons will still encounter patients who have undergone this surgery and now have separate or related upper gastrointestinal pathology.

ANATOMY

Oesophagus

The oesophagus is an epithelial lined muscular tube that lies mainly in the superior and posterior mediastina. It commences in the neck as a continuation of the pharynx, with its upper end encircled by the cricopharyngeal sphincter. The bodies of the cervical vertebrae lie posterior to the oesophagus and the trachea lies immediately anteriorly. The recurrent laryngeal nerves lie in the groove between the oesophagus and the trachea. Anteriorly in its intrathoracic course, the oesophagus is related first to the trachea, followed by the right pulmonary artery and then the pericardium. Throughout its course it lies on the bodies of the thoracic vertebrae. It passes through the diaphragm in a hiatal sling formed mainly by the fibres of the right crus. Its final 2 cm is as an intraperitoneal organ before it terminates at the *cardia*, or oesophagogastric junction. Oesophagogastric reflux is prevented by a functional lower oesophageal sphincter, which is dependent more on the distal portion of the oesophagus lying intra-abdominally and the angle at which it enters the stomach, than on any anatomical sphincter at the cardia. The vagus nerves form a plexus on either side of the oesophagus, but at the level of the hiatus the left vagus lies anteriorly and the right vagus posteriorly. The epithelial lining is squamous, except for the distal 2 cm where there is a variable transition zone to gastric mucosa.

Arterial supply

The arterial supply to the oesophagus is from the inferior thyroid artery from above and the left gastric and inferior phrenic arteries from below, and in its middle portion it is also supplied by bronchial arteries and small branches directly from the aorta. There is an extensive anastomosis between the arteries in the muscular and submucosal layers of the oesophageal wall. A *submucosal venous plexus* connects with that of the stomach and becomes varicose in portal hypertension, allowing portal venous blood to pass via the azygos vein to the superior vena cava.

Lymphatic drainage

There is an extensive lymphatic plexus in the submucosal layer of the oesophageal wall. This connects with another extensive para-oesophageal plexus, where lymph from the entire length of the oesophagus can mix before finally draining to cervical, thoracic and abdominal lymph nodes. Lymphatic drainage then follows the arterial supply.

Stomach

The stomach is divided, mainly for descriptive purposes, into three major zones (Figure 17.1). The fundus lies above the oesophagogastric junction. The angle of His is the acute angle between the fundus and the oesophagus. The body is below the oesophagogastric junction and is limited distally by the incisura angularis, a somewhat variable angulation of the lesser curve. The antrum is the portion of stomach distal to the incisura and extends to the pylorus. The pyloric sphincter is a condensation of the circular muscle of the stomach.

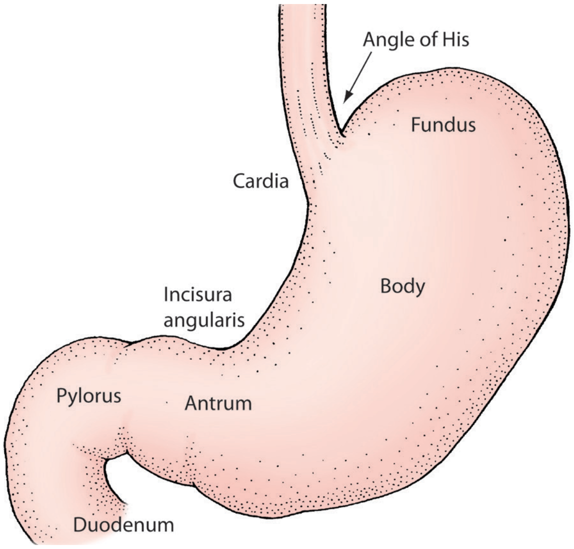
Angle of His
Fundus
Cardia
Body
Incisura angularis
Pylorus
Antrum
Duodenum

Figure 17.1 *The stomach.*

The stomach is completely invested in peritoneum, except for a small area posteriorly just below the cardia. The peritoneal coverings of the anterior and posterior walls of the stomach meet at the lesser curve and pass upwards as the lesser omentum, or gastrohepatic ligament, to the porta hepatis and a fissure on the posterior aspect of the liver. At the greater curve the peritoneal layers meet to form the greater omentum and the gastrosplenic and gastrophrenic ligaments. These peritoneal folds around the stomach, and the subsequent division of the peritoneal cavity into a greater and lesser sac (see Figure 14.4, p. 230), are easier to understand from an embryological viewpoint (see Figure 14.3, p. 229). As they are important to all surgeons operating within the abdomen, this topic was covered in Chapter 14. The mucosa of the body and fundus of the stomach contain *parietal cells*, which secrete acid, and *chief cells*, which secrete pepsinogen. The mucosa of the antrum contains gastrin-secreting *G cells*, which stimulate the parietal cells to secrete acid.

Arterial supply

The arterial supply to the stomach is almost exclusively from the coeliac axis, which arises from the aorta behind the lesser sac. The branches to the stomach enter the extremities of the lesser and greater omenta to form two arterial arcades, which lie between the peritoneal folds, 1–2 cm from the stomach wall. Multiple branches from these arcades pass to the lesser and greater curve (Figure 17.2). The gastric arcade, within

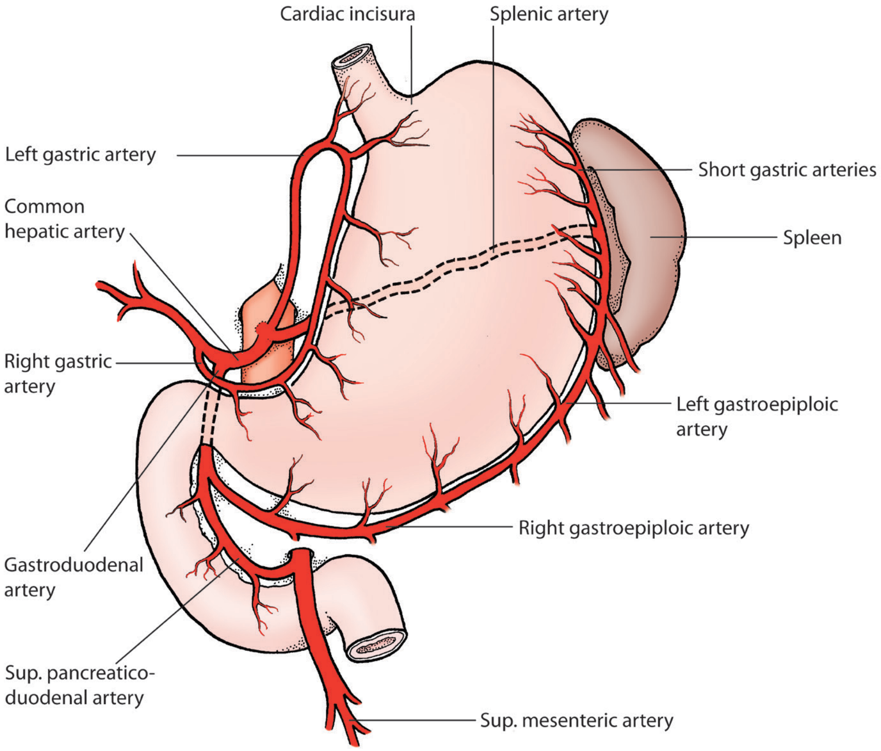
Cardiac incisura
Splenic artery
Left gastric artery
Common hepatic artery
Short gastric arteries
Spleen
Right gastric artery
Left gastroepiploic artery
Right gastroepiploic artery
Gastroduodenal artery
Sup. pancreatico-duodenal artery
Sup. mesenteric artery

Figure 17.2 *Arterial supply to the stomach and proximal duodenum.*

the lesser omentum, is formed by the descending branch of the left gastric artery and the right gastric branch of the common hepatic artery. The gastroepiploic arcade, within the greater omentum, is formed by the right gastroepiploic branch of the gastroduodenal artery and the left gastroepiploic branch of the splenic artery. In addition, the upper part of the greater curve receives some four or five short gastric arteries from the splenic artery or one of its terminal branches. It is this rich anastomotic blood supply from several arteries converging from different directions that makes much of gastric surgery possible. There are also collateral anastomoses, both with branches of the superior mesenteric artery supplying the duodenum and with the aortic branches supplying the oesophagus. For this reason, gastric ischaemia in occlusive vascular disease is very uncommon, even when the coeliac axis is completely occluded. The venous drainage of the stomach is into the portal system, except for the alternative systemic route via the submucosal venous plexus, across the oesophagogastric junction and into the azygos vein.

Lymphatic drainage

The lymphatic drainage of the stomach follows its arterial supply, in a similar fashion to the pattern encountered throughout the gastrointestinal tract (see Chapter 16). The main lymphatic channels are therefore initially along the gastric and gastroepiploic arterial arcades, and the perigastric lymph nodes lie alongside the vessels. The lymphatics then accompany the main arteries supplying the stomach to their origin from the aorta. Further nodes lie alongside the retroperitoneal routes of these arteries, and the lymph finally drains into the preaortic nodes. There are anastomotic lymphatic channels that have a similar function to arterial collaterals and become of greater importance when the main channels are blocked by tumour. Knowledge of the lymphatic drainage of the stomach has important implications for the staging and treatment of gastric cancer.[1] Nodes have been named and numbered. They have also been divided into 'tiers' of lymph nodes to which gastric cancer may spread in a progressive fashion. As a simplification this can be viewed as:

- 1st tier (N1) – perigastric nodes closest to the tumour.
- 2nd tier (N2) – further more distant perigastric nodes and nodes along the course of the main artery that supplies the area of stomach from which the tumour has arisen.
- 3rd tier (N3) – nodes outside these main pathways.

Resections can now be planned to excise all N1 nodes, to excise all N1 and N2 nodes or even to include some N3 nodes. However, this is complicated by the different lymphatic drainage in different areas of the stomach, and an N1 node for a pyloric cancer will be an N2 node for a cancer at the cardia. Gastric lymphadenectomy is discussed in more detail in the sections on gastric cancer, both later in this chapter and in Chapter 18.

Nerve supply

The stomach has both sympathetic and parasympathetic innervation, the latter being provided by the vagus nerves. Shortly after emerging from the oesophageal hiatus, the anterior vagus gives off hepatobiliary fibres and the posterior vagus a branch to the coeliac plexus. There are also branches to the cardia. The main trunks continue as the anterior and posterior nerves of Latarjet (Figure 17.3). The nerves of Latarjet supply multiple further branches to the body of the stomach, with each branch passing into the stomach wall close to a vascular pedicle. These fibres are motor to the upper stomach but, more importantly, stimulate the secretion of acid by the parietal cells. They are divided in the operation of highly selective vagotomy. The nerves of Latarjet continue towards the antrum, to end in a configuration known as the 'crow's foot', which innervates the myenteric plexus of the antrum. The terminal crow's foot is preserved in a highly selective vagotomy, as it is a motor nerve to the pylorus from the anterior vagus, on which effective gastric emptying depends.

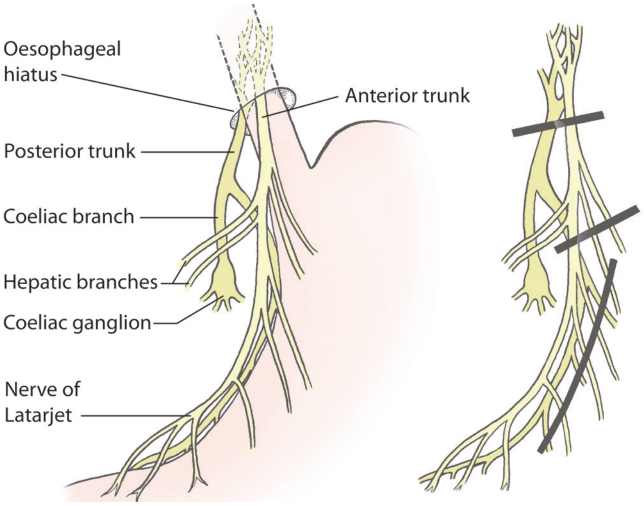

Figure 17.3 *Vagal innervation of the stomach. The three bars indicate the level of transection in truncal vagotomy, selective vagotomy and highly selective vagotomy.*

Duodenum

The duodenum commences at the pylorus. After the first 2–3 cm it loses much of its peritoneal covering and becomes a retroperitoneal, relatively fixed segment of the small bowel until the duodenojejunal flexure, where the bowel again becomes mobile on a mesentery. The duodenum is curled around the head of the pancreas so that its *first part* lies horizontally above it, the *second part* vertically to its right and the *third part* horizontally below it. The *fourth part* then ascends to the left of the aorta. The bile and pancreatic ducts enter the concave medial wall of the second part at the *ampulla of Vater.* The duodenum is intimately related to the hilum of the right kidney, the hepatic flexure of the colon and the aorta, in addition to the pancreas. It thus forms a landmark during many intra-abdominal dissections, and must often be mobilised during pancreaticobiliary, renal and aortic surgery (see Figure 14.2, p. 229).

Arterial supply

The duodenum is supplied from both the coeliac axis and the superior mesenteric artery (see Figure 17.2). The superior pancreaticoduodenal artery, the inflow of which is from the coeliac axis, and the inferior pancreaticoduodenal branch of the superior mesenteric artery form an arcade around the head of the pancreas. Most of the arterial supply to the duodenum is from this arcade, although there are additional branches that cross the pylorus, to the first part of the duodenum, from the gastric and gastroepiploic arteries.

HELLER'S CARDIOMYOTOMY

The principle underlying this operation for achalasia is to reduce the lower oesophageal sphincter pressure by dividing the muscle wall, while avoiding any breach of the underlying mucosa. The myotomy consists of longitudinal division of the muscle fibres of the lower oesophagus, and should extend across the oesophagogastric junction for 1–2 cm to ensure the division of all constricting muscle fibres. Traditionally, an extensive myotomy was performed through a left posterolateral thoracotomy. However, many surgeons questioned the need for such an extensive proximal myotomy in classical achalasia, as the principal dysfunction is across the oesophagogastric junction and lower oesophagus. A more limited myotomy can be performed from the abdomen, and the thoracic approach is now mainly reserved for the motility disorders involving the whole oesophagus where a more extensive myotomy is needed. Most centres when considering surgical intervention will nowadays use a minimally-invasive thoracoscopic or laparoscopic approach.

Preoperative management prior to a Heller's cardiomyotomy includes the insertion of a wide-bore nasogastric tube, but removal of solid food retained in the dilated oesophagus is still difficult. The anaesthetist should be aware of the aspiration risk during induction and should protect the airway appropriately. Broad-spectrum antibiotic prophylaxis is usually recommended on induction.

Laparoscopic Heller's cardiomyotomy

Some surgeons favour the views provided from operating on the patient's left side but there are advantages in the lithotomy position, which allows the surgeon to operate from between the legs, using a port placement as shown in Figure 17.4a. The first camera port is inserted midway between the umbilicus and xiphisternum, using an open Hasson's technique, thereby creating a pneumoperitoneum to 15 mmHg using CO_2 insufflation. An angled 30 degree lens is used for the procedure. A non-traumatic liver fan-type retractor is inserted through the right hypochondrial port to elevate the left lobe of the liver and allow visualisation of the oesophagogastric junction. A Babcock forceps placed through the left inferior port allows the stomach to be retracted inferiorly and laterally, putting the gastrohepatic ligament on stretch. It is important to avoid tearing the stomach with excess traction. The thin, transparent gastrohepatic ligament is then divided using diathermy (or ultrasonic) dissection via the left hypochondrial port. This should be a bloodless dissection, and usually commences superior to the hepatic branches of the vagus nerve. These vagal fibres innervate the gallbladder and liver, with proponents of preservation citing increased gallbladder stasis and cholelithiasis when they are divided. However, if they interfere with access, then they may have to be sacrificed. Occasionally, an aberrant left hepatic artery is encountered in this plane and can be safely divided.[2]

As the dissection continues, the right sling of the diaphragmatic crus is exposed. If the achalasia segment is extensive, further oesophageal mobilisation, as for a laparoscopic fundoplication, may be required.

A flexible endoscope is inserted to facilitate the myotomy. It is imperative that the anterior vagus nerve is identified and isolated prior to myotomy (Figure 17.4b). The nerve usually lies in close approximation to the anterior oesophagus, in contrast to the posterior vagus nerve, which lies more freely in the posterior oesophageal plane. The myotomy is commenced 1–2 cm distal to the oesophagogastric junction using coagulating shears or hook dissection. However, these techniques carry the inherent risk of thermal injury to the underlying mucosa, particularly in the presence of fibrosis, and thus many surgeons favour scissors alone for this part of the procedure. The dissection may be commenced more distally if there is oesophageal scarring secondary to previous treatment such as pneumatic dilatation or the use of botulinum toxin.

The anterior longitudinal muscle fibres are divided, exposing the underlying circular fibres. The circular fibres can then be elevated off the submucosa and divided (Figure 17.4c). The flexible endoscope is used to transilluminate the working field, reducing the potential for mucosal breach. The myotomy is extended proximally for 4–6 cm, at which stage the dilated proximal portion of oesophagus should have been reached. Incomplete myotomy is a common cause of failure following a Heller's procedure. Bleeding from the anterior oesophageal wall is usually self-limiting, and excessive blind use of diathermy should be avoided.

When the myotomy is complete, saline is injected around the working field and air insufflated via the endoscope (Figure 17.4d). The presence of bubbles, as from a punctured tyre, indicates a mucosal breach requiring immediate repair. The defect may be closed by laparoscopic suturing, but if it is more extensive, it requires conversion to an open procedure. When there has been any concern, water-soluble contrast studies help to confirm oesophageal integrity prior to allowing oral intake.

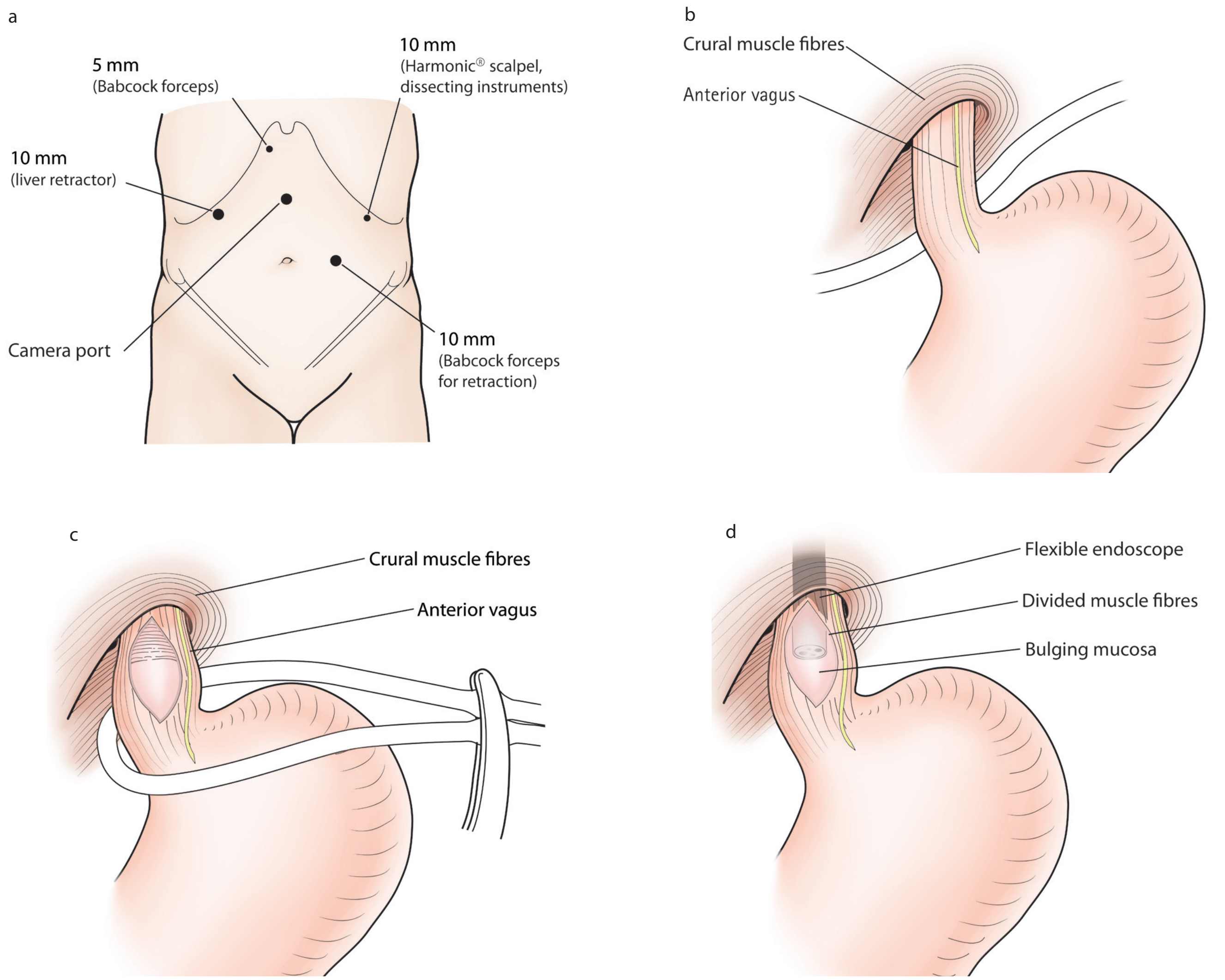
a
5 mm
(Babcock forceps)
10 mm
(Harmonic® scalpel,
dissecting instruments)
10 mm
(liver retractor)
Camera port
10 mm
(Babcock forceps
for retraction)
b
Crural muscle fibres
Anterior vagus
c
Crural muscle fibres
Anterior vagus
d
Flexible endoscope
Divided muscle fibres
Bulging mucosa

Figure 17.4 *Heller's cardiomyotomy. (a) Port positions for a laparoscopic Heller's cardiomyotomy or a Nissen fundoplication. (b) The vulnerable position of the anterior vagus nerve. (c) Division of the longitudinal muscle fibres and the underlying circular muscle fibres to expose the mucosa. (d) Air insufflation via the flexible endoscope to confirm integrity of the mucosa following completion of the myotomy.*

The decision to include a fundoplication is taken on a case-by-case basis. If the perihiatal dissection is minimal, a fundoplication is generally not required. If there has been an oesophageal mucosal injury, then a Dor partial anterior fundoplication provides good mucosal protection (see below). Here, the anterior fundus is anchored to the free edges of the myotomy, in addition to the hiatus, via placement of three sutures on each side.

THORACOSCOPIC APPROACH

The thoracoscopic approach to a cardiomyotomy may be performed through the left or right thoracic cavity and is usually reserved for patients where a more extensive myotomy is indicated. A thoracic approach allows the myotomy to be extended from the diaphragm to the level where the oesophagus is crossed by the aorta or azygos vein. A right-sided approach has the advantage that the azygos vein can be divided if further proximal extension of the myotomy is required. The general principles of video-assisted thoracoscopic surgery were covered in Chapter 8. Underlying lung disease, with associated pleural adhesions, increases the risk of this approach. Damage to lung parenchyma can occur during port insertion despite the use of double-lumen tubes, as adhesions can prevent the lung from collapsing. The first port, which will be used for the camera, is placed inferior to the tip of the scapula through the sixth intercostal space. If the lung is not fully collapsed, then insufflation with CO_2 to a maximum pressure of approximately 5 mmHg, creating a low-pressure pneumothorax, may be helpful. If there is any cardiorespiratory disturbance during the procedure, the CO_2 is released immediately. The positions of the working ports vary between surgeons, but placing two further ports anterior to the mid-axillary line through the fifth and seventh intercostal spaces is a satisfactory arrangement. A fourth port can then be inserted more anteriorly through the sixth intercostal space and this can be used by the assistant to retract the lung. If the patient has underlying cardiorespiratory disease and tolerates single-lung ventilation poorly, the collapsed lung may be inflated periodically throughout the procedure. The inferior pulmonary ligament is divided. The assistant retracts the lung superiorly, and careful division of the mediastinal pleura exposes the lateral wall of the oesophagus. Division of the phreno-oesophageal membrane will allow the gastric fundus to be brought up into the chest, with division of some short gastric vessels if there is undue tension during gastric mobilisation. Care must be taken not to damage the vagi. As in the laparoscopic approach, the longitudinal muscle fibres are divided, followed by the underlying circular fibres, until the mucosa is seen to bulge. The flexible endoscope facilitates this dissection and reduces the potential for mucosal perforation. When the myotomy is completed the edges of the muscle fibres are dissected off the mucosa to minimise subsequent scarring and stricture formation. Thereafter, an anti-reflux procedure may be added; either a modified Belsey fundoplication or a Dor partial fundoplication (see below).

Again, at the end of the procedure an air insufflation test is performed and a chest drain inserted prior to lung reinflation.

ANTI-REFLUX SURGERY

A great variety of different operations have been developed over the years for the treatment of oesophagogastric reflux. The principles of surgery, irrespective of the technique used, include:

- Restoration of an intra-abdominal portion of oesophagus to maintain a pressure differential between the thoracic and abdominal oesophagus.
- Creation of a loose wrap around the oesophagogastric junction to restore the mechanical effect of the oesophagogastric junction.
- Reduction of any hiatus hernia and approximation of the crural fibres to narrow the oesophageal hiatus.
- Identification and management of any associated anatomical abnormalities such as a shortened oesophagus.

BELSEY MARK IV

Before the advent of the laparoscopic era, the Belsey Mark IV was the gold standard operation. It is a partial anterior wrap, undertaken through a left sixth intercostal space posterolateral thoracotomy. The oesophagus is mobilised from the level of the aortic arch to the cardia, thus freeing it from its diaphragmatic attachments. It may be necessary to divide the superior and inferior bronchial arteries and the oesophageal branches of the distal descending thoracic aorta. The gastric fundus is plicated to the lower 4 cm of the oesophagus for 270 degrees anteriorly and laterally, while leaving the posterior quarter of the oesophagus and the posterior vagus nerve undisturbed. The repair is carried out in two layers. The first layer of sutures attaches the gastric fundus to the lower 2 cm of the oesophagus and the second layer includes bites of the oesophagus, the fundus of the stomach and the tendinous portion of the diaphragm (Figure 17.5). The posterior segment of oesophagus not included in the wrap is buttressed against the hiatus. Sutures are placed posteriorly in the crural opening to narrow the hiatus.

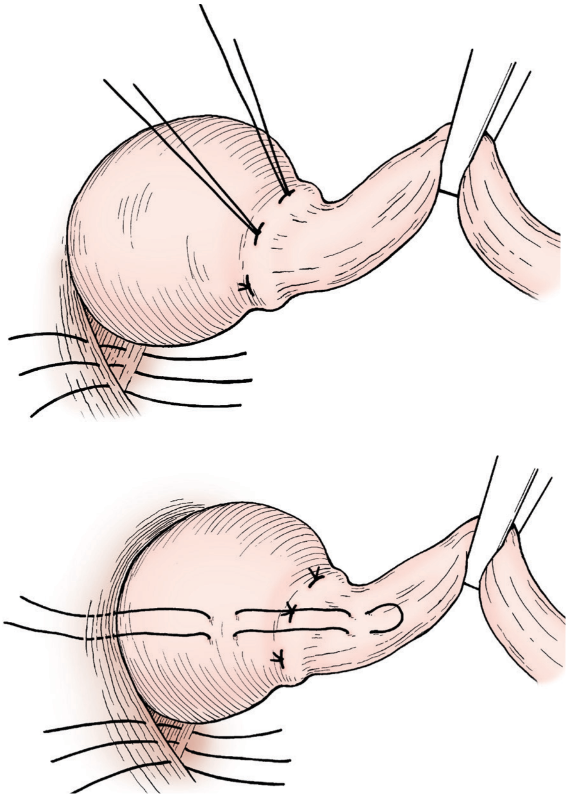

Figure 17.5 *Belsey Mark IV procedure.*

COLLIS GASTROPLASTY

The Collis gastroplasty also dates from the pre-laparoscopic era. It is designed to give a tension-free repair for patients with a hiatus hernia in combination with a shortened oesophagus. The technique consists of isolating the upper part of the lesser curve in the form of a tube in continuity with the oesophagus. The distal end of this tube can then be considered as the new oesophagogastric junction and several centimetres of the neo-oesophagus can now lie below the diaphragm. A method more suitable for the access available at an open thoracotomy approach is shown in Figures 17.6a and 17.6b. At laparoscopy, access may make an alternative manoeuvre easier; a wedge of stomach is removed by repeated application of a laparoscopic stapler (Figure 17.6c). Alternatively, with a 48-gauge bougie in place, an opening through the anterior and posterior wall of the stomach can

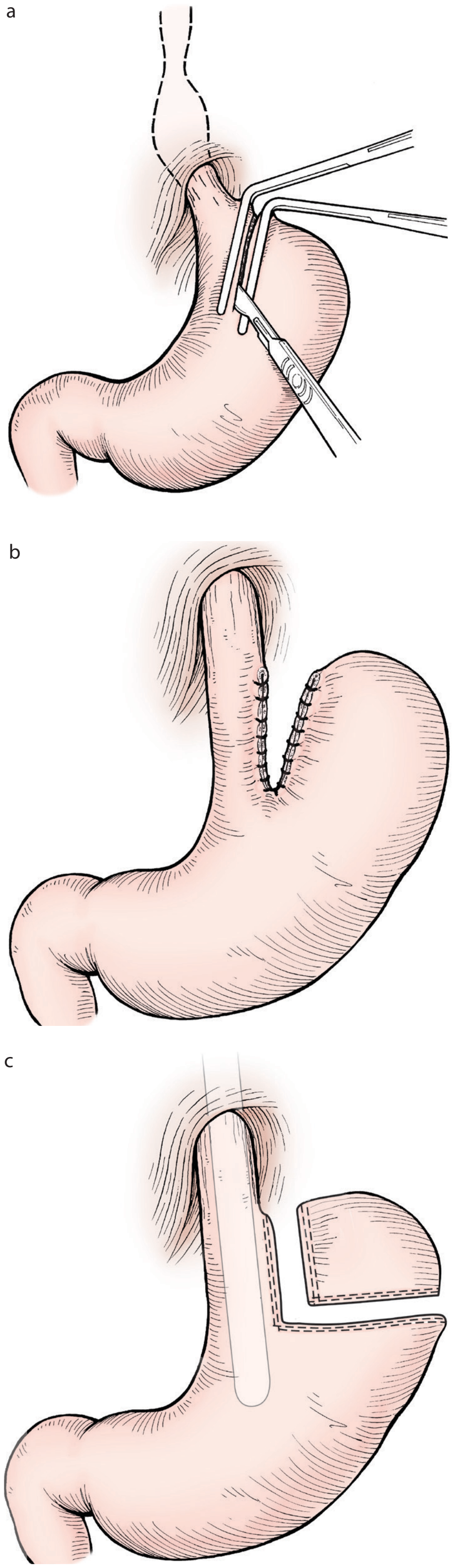

Figure 17.6 *(a) and (b) A Collis gastroplasty. Alternatively, a combination of circular and linear stapling devices can be used in a similar manoeuvre to that shown in Figure 18.8 (p. 304) except that the linear stapling must be performed with a cutting device. (c) A wedge resection produces a similar result.*

be made with a circular stapling device and then a linear cutting stapling device is passed from this opening to the angle of His. After firing of this cutting stapler, the anatomical result will be similar to that shown in Figure 17.6c. An anti-reflux procedure is then performed around the neo-oesophagus to control reflux. Although anatomically a Collis gastroplasty is an attractive solution, function may be poor as this distal neo-oesophagus does not coordinate with the oesophageal peristaltic wave during swallowing and it continues to secrete acid.

Nissen fundoplication

This is a full (360-degree) posterior wrap around the lower 4 cm of the oesophagus. Although originally undertaken either through a laparotomy incision or through a left posterolateral sixth intercostal space thoracotomy, it is now a standard laparoscopic procedure.

A similar placement of ports to that employed for a laparoscopic Heller's procedure is suitable (see Figure 17.4). The surgeon stands between the patient's legs, while the first assistant stands to the right of the patient, operating the camera with the right hand. A liver retractor is inserted through the right hypochondrial port, allowing elevation of the left lobe of the liver with the assistant's left hand. The second assistant stands on the left-hand side, primarily for stomach retraction using a Babcock forceps inserted through the left inferior port. Harmonic® coagulation shears are useful for the dissection (see Chapter 1, p. 7).

The liver retractor allows access and visualisation of the working field. A Babcock forceps is placed on the stomach and retracted inferiorly and laterally to place the gastrohepatic ligament on stretch. This tissue is usually avascular and it is divided distal to the hepatic branch of the vagus nerve up to the level of the right diaphragmatic crus. However, these vagal fibres are sacrificed if they limit visualisation of the oesophageal hiatus. An aberrant left hepatic artery may be encountered in this region. Most surgeons are nervous about dividing this vessel because of the potential risk of hepatic ischaemia. However, division is not associated with significant adverse hepatic effects.[2] It may be ligated with standard clips or sealed with Harmonic® shears. It is important to remember the proximity of the inferior vena cava, lying between the caudate lobe and the right crus, as injury to this vessel can result in catastrophic haemorrhage.

Having identified the right crus, the phreno-oesophageal ligament overlying the distal oesophagus and oesophagogastric junction is then divided, taking care not to damage the underlying oesophagus or anterior vagus nerve. Caudal traction on the fundus will help to identify the distal oesophagus. Careful dissection will expose the posterior vagus nerve, which must be preserved, and also the confluence of the crural muscle fibres behind the oesophagus. If the oesophagogastric fat pad is large, it is excised. The gastric fundus is then retracted to the patient's right. At this stage the upper short gastric vessels can be divided. There has long been a difference of opinion between surgeons as to whether or not this is an essential step in achieving complete fundal mobilisation. It would now appear that, in general, division of the short gastric vessels is not necessary.[3,4] The left crural sling is identified and a space created between the crural fibres and the posterior aspect of the oesophagus. On returning to the right side, the posterior oesophageal window is easily opened with minimal dissection.

The gastric fundus is then pulled gently through the posterior oesophageal window using the *shoe-shine* technique. This consists of placing a Babcock forceps on the gastric fundus as it emerges from the posterior oesophageal window, and a second forceps on the splenic side. Gentle traction back and forth between the forceps allows emergence of the wrap without tearing. Some surgeons favour the use of a roticulator, but it can be argued that if this is required, then the oesophageal window has been inadequately mobilised, and tension on the wrap may ensue. Tension may increase the risk of wrap disruption and postoperative dysphagia.

Two 2/0 non-absorbable sutures are used to plicate the gastric wrap. It is important that the wrap is not too tight. If one of these sutures incorporates the muscular coat of the intra-abdominal oesophagus (Figure 17.7a), the potential for wrap slippage is reduced. The crural fibres are then approximated using two to three 2/0 non-absorbable sutures to narrow the oesophageal hiatus (Figure 17.7b). This also reduces the likelihood of intrathoracic migration of the wrap. While narrowing the hiatus may increase the incidence of postoperative dysphagia, this is usually transient. If the dysphagia persists, a crural stitch may be removed laparoscopically.

Partial wraps

There is a wide variety of partial wraps available.

TOUPET FUNDOPLICATION

The Toupet procedure is the most commonly used laparoscopic partial fundoplication. It is a partial posterior wrap and the initial steps are similar to those for a laparoscopic Nissen fundoplication. Again, the short gastric vessels can be divided, facilitating fundal mobilisation. The posterior oesophageal window is created and the gastric fundus eased through. The right leading limb of the fundus is then sutured to the right anterior aspect of the oesophagus, taking care not to damage the anterior vagus nerve or incorporate it in the stitch. The lateral left aspect of the fundus is then sutured to the anterolateral aspect of the oesophagus (Figure 17.8). The fundus may be further sutured to the crura to prevent wrap rotation.

DOR FUNDOPLICATION

This is a partial anterior fundoplication that can be used to provide good mucosal protection after a cardiomyotomy. The fundus is brought up anterior to the oesophagus and sutured to its right and left sides. Other anterior partial fundoplications have also been described and these include a variable proportion of the oesophageal circumference in the wrap. The original Belsey Mark IV is an anterior partial fundoplication.

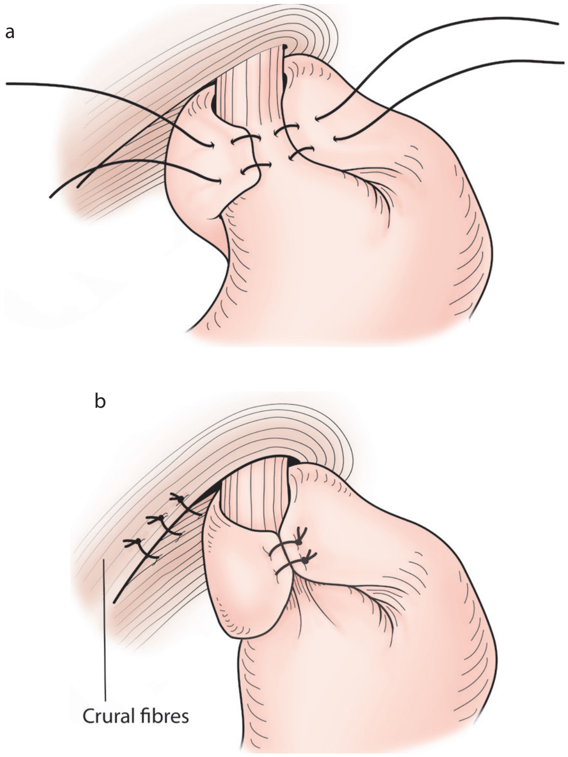

Figure 17.7 *Nissen fundoplication. (a) When creating the wrap, one or more of the sutures must incorporate the abdominal oesophagus to prevent wrap migration. (b) Closure of the hiatal defect by approximation of the crural fibres.*

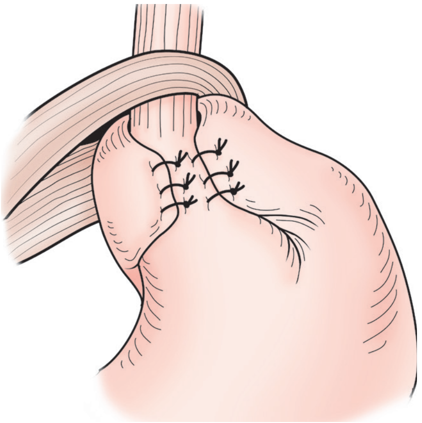

Figure 17.8 *Completed Toupet partial fundoplication.*

Intraoperative complications

During any anti-reflux operation there is potential for splenic injury in addition to gastric or oesophageal perforation. The incidence of perforation is reported as 1 per cent and this carries a significant risk of morbidity and mortality, particularly if not recognised at the time. The mechanism may involve a tear from excessive traction during the dissection or a delayed necrotic injury due to thermal energy. It is believed that the use of ultrasonic coagulation shears may reduce the potential for thermal injury. Intraoperative insertion of a bougie or nasogastric tube has also been reported as a possible cause of perforation. Occasionally, a suture, if under excessive tension, can cut through the gastric or oesophageal tissue, leaving a perforation. If recognised intraoperatively, the perforation can be repaired. For anterior oesophageal perforations, interrupted sutures can be inserted laparoscopically but posterior perforations, due to difficulty of access, may require conversion to an open procedure. Gastric perforations can be closed using an endoscopic gastrointestinal stapling device.

Postoperative complications

Dysphagia

In most scenarios, any postoperative dysphagia after Nissen fundoplication is transient and settles within a few days, but if it persists and is disabling, then a check endoscopy is performed. The oesophageal lumen may be compromised because of excessive closure of the hiatal opening, a tight wrap or inadequate mobilisation of the gastric fundus. If the endoscope passes freely to the stomach, dilatation is carried out with care, and this usually gives a good functional result. Most patients will respond to dilatation, although a small number will require reoperation. If endoscopy identifies complete obstruction of the distal oesophageal lumen, the patient is relaparoscoped and the wrap assessed. Usually, the upper stitch on the crural fibres is the offending agent and when it is removed the endoscope passes freely. Very occasionally, the full Nissen wrap has to be converted to a partial wrap.

Wrap migration

Herniation of the fundoplication through the hiatal opening into the chest is a cause of failure (Figure 17.9a). This may occur because of inadequate closure of the crural defect at the time of repair. However, it is important when closing the defect to balance adequate closure against the risk of strangulation and dysphagia. Many surgeons insert a stitch to anchor the distal oesophagus and prevent migration and rotation of the wrap. Other risk factors thought to contribute to intrathoracic migration include an early return to strenuous exercise and postoperative vomiting. Patients with a very large hiatal opening may also be at increased risk. In many cases, failure to recognise a shortened oesophagus is a significant cause. The patient may complain of sudden onset of epigastric or substernal pain rather than reflux symptoms. This iatrogenic para-oesophageal herniation represents a surgical emergency, as the herniated fundus can strangulate, and it must be repaired as soon as the patient is stabilised.

Occasionally, the wrap may slip down the stomach and this is more likely to occur if too distal a portion of stomach has been used for the wrap (Figure 17.9b). Again, incorporation of the distal oesophagus when suturing the wrap anteriorly will reduce the potential for this complication.

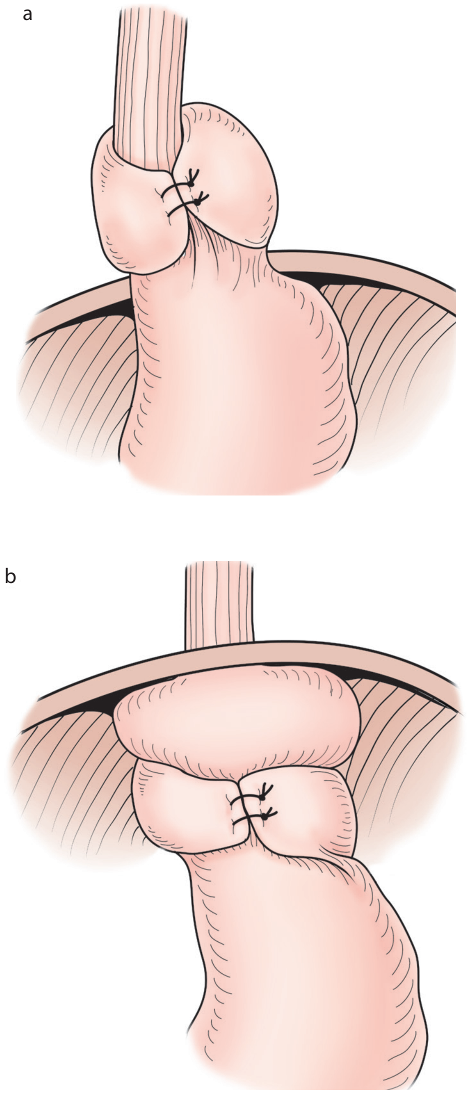

Figure 17.9 *Wrap migration. (a) Up through the hiatus into the chest. (b) Down around the stomach.*

VAGOTOMY

Vagotomy abolishes vagal stimulation of the parietal cell mass and reduces gastric acid production. Three different vagotomies are shown diagrammatically in Figure 17.3. For many years, after first being reported in 1949,[5] these operations were important in securing the healing of peptic ulcers. The present, ever diminishing role for vagotomy is discussed in more depth in Chapter 18 and here only a brief description is given of these now almost historic operations.

A *truncal vagotomy* denervates the whole stomach and must be combined with a gastric drainage procedure such as a pyloroplasty or a gastrojejunostomy. It also denervates the gallbladder, predisposing to gallstone formation, and the small intestine, which is a contributory factor in post-vagotomy diarrhoea. Through an upper midline incision the stomach is gently retracted downwards and the oesophagus identified (easier if a nasogastric tube is *in situ*). The overlying peritoneum is incised and the anterior vagal trunk, which is double in 15 per cent of people, is usually easily visualised but if not, it can be palpated as a taut band. It is divided – ligation or diathermy of the cut ends is recommended because of an accompanying small vessel. The posterior vagal trunk – double in only 1 per cent of people – is found between the right crus and the oesophagus and is similarly divided. It may give off some proximal branches to the gastric fundus, which must also be identified and divided.

A *selective vagotomy* preserves the hepatic and coeliac branches of the vagal trunks. Although some advantages over truncal vagotomy are claimed, a gastric drainage procedure is still required. The anterior and posterior vagal trunks are isolated as for a truncal vagotomy but, in order that they can be divided distal to their hepatic and coeliac branches, these branches must also be identified and preserved. Proximal branches from the vagi to the cardia must again be identified and divided.

A *highly selective vagotomy* denervates only the parietal cell mass, while preserving motor innervation of the antrum. No drainage procedure is necessary. Attention to detail is important if results are not to be diasappointing. Good access requires division of the left triangular ligament so that the left lobe of the liver can be retracted inferiorly. The anterior nerve of Latarjet is usually clearly visible, some 1–2 cm from the lesser curve. As it approaches the antrum it fans out into several branches, the appearance of which is described as the 'crow's foot'. This crow's foot is left wholly or partially intact to secure innervation of 5–6 cm of antrum. The denervation of the parietal cell mass requires all tissue between the nerves and the lesser curve proximal to this to be divided. The anterior leaf of the lesser omentum is incised and each neurovascular bundle is secured as close to the lesser curve as possible. Dissection is then deepened to separate the posterior nerve in a similar fashion (Figure 17.10). In addition, the lower oesophagus should be cleared for 7–8 cm to divide any vagal fibres passing down on its wall and the fundus should also be cleared as far as the first short gastric vessels. A sling around the oesophagus and a second sling around the vagal trunks are useful for retraction at this stage.

Posterior truncal vagotomy with anterior seromyotomy also avoids a gastric drainage procedure and is a simpler and quicker operation than a highly selective vagotomy. The anterior seromyotomy follows the lesser curve at a distance of 2 cm from it, starting at the angle of His and extending to approximately 5 cm from the pylorus. Care must be taken not to breach the gastric mucosa.

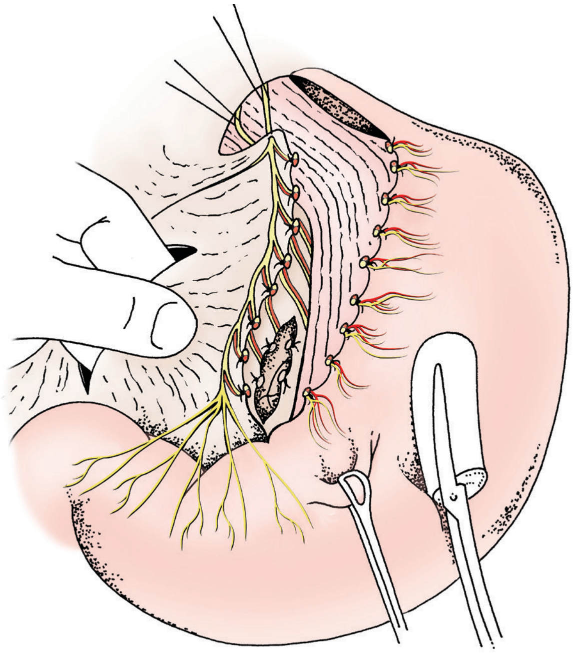

Figure 17.10 *Highly selective vagotomy. The division of the neurovascular bundles in the anterior leaf of the lesser omentum has been completed and the dissection of the branches from the posterior vagus has been started. The peritoneal incision has been carried over the front of the cardia so that the distal oesophagus can be cleared.*

GASTRIC DRAINAGE PROCEDURES

Gastric drainage is required in a wide range of scenarios. For example, there may be a mechanical obstruction of the pylorus or duodenum or the distal stomach may have been resected or excluded. The operation may also be performed to improve gastric drainage after a vagotomy.

Gastrostomy

A gastrostomy is only suitable as a temporary form of gastric drainage. A tube gastrostomy is occasionally established at the time of surgery as an alternative to nasogastric aspiration. It may be more comfortable than a nasogastric tube and is associated with fewer respiratory complications. The technique is described in Chapter 14. More often, a gastrostomy is required not for drainage but for enteral feeding, and endoscopic insertion is usually more appropriate in these circumstances (see Chapter 12).

Pyloroplasty

Pyloroplasty is most frequently performed in combination with a vagotomy; this procedure improves gastric drainage by destroying the sphincter effect of the pylorus. The prelude to any type of pyloroplasty is adequate mobilisation of the second part of the duodenum by full Kocherisation. In this manoeuvre a peritoneal incision is made lateral to the second part of the duodenum to enter the areolar plane behind the duodenum and pancreatic head. As the dissection in this plane is continued towards the midline, the duodenum and pancreas can be lifted forwards off the kidney and inferior vena cava (see also Chapter 14).

HEINEKE–MIKULICZ OPERATION

The Heineke–Mikulicz operation has undergone several modifications since its original description, but is in essence a longitudinal incision across the pylorus, which is then closed transversely. Two deep stay sutures are inserted 1 cm apart in the anterior aspect of the pyloric ring. A 6-cm longitudinal incision is then made between the sutures into the lumen. Traction on the stay sutures converts the longitudinal incision into a diamond-shaped opening, which is closed transversely using a single layer of interrupted absorbable sutures such as 3/0 polydioxanone (PDS®) (Figure 17.11). Further layers of sutures, as originally described, are no longer recommended as they narrow the pyloric channel. The pyloroplasty may then be buttressed with omentum. This operation is not feasible if the pylorus is grossly thickened or scarred. The operation can be carried out at open surgery or laparoscopically.

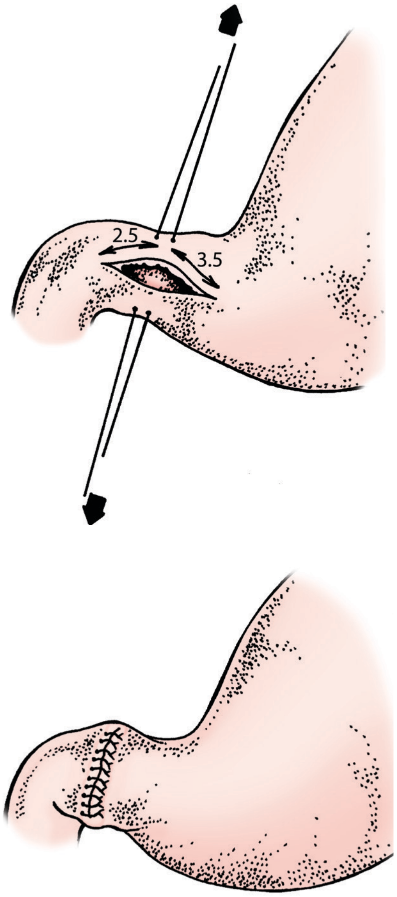

Figure 17.11 *Heineke–Mikulicz pyloroplasty.*

FINNEY'S PYLOROPLASTY

Although often described as a pyloroplasty, Finney's pyloroplasty is really a gastroduodenostomy (Figure 17.12). Its only advantage over a Heineke–Mikulicz operation is that it is still a possible option in situations where scarring is more severe. However, in these circumstances most surgeons would opt for a gastroenterostomy.

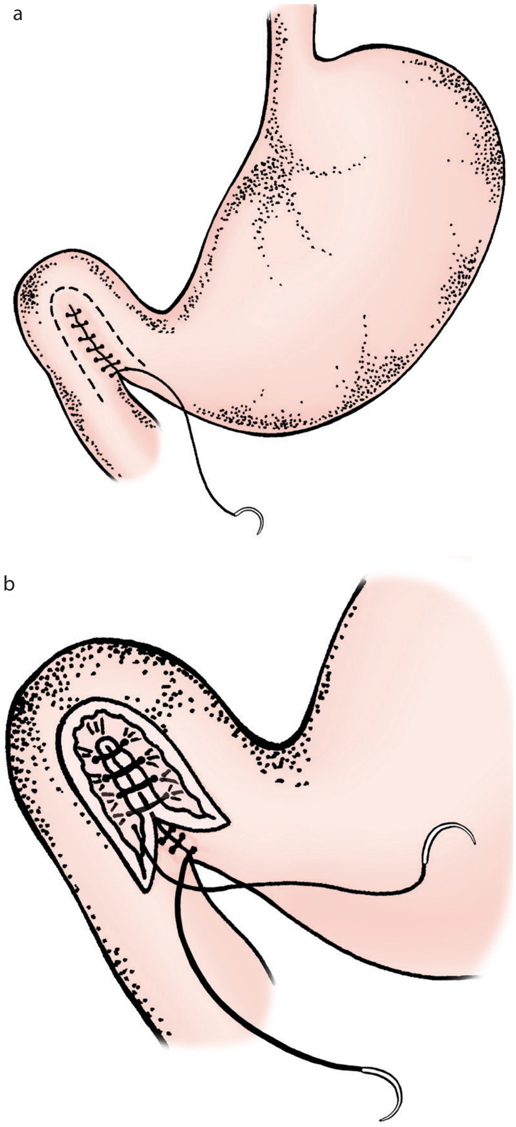

Figure 17.12 *Finney's gastroduodenostomy. (a) A posterior seromuscular suture is inserted before an inverted U-shaped incision is made. (b) The posterior all-layer suture has been started. It will be continued round anteriorly to close the opening into the lumen. The posterior seromuscular suture is then carried round over this all-layer suture.*

PYLORIC DILATATION AND PYLOROMYOTOMY

The pyloric sphincter mechanism can also be disrupted by *pyloric dilatation* or formally divided by *pyloromyotomy*, in which the muscle is incised longitudinally but the mucosa is preserved intact. These are options employed to improve drainage from the intrathoracic gastric conduit used for reconstruction after oesophagectomy. The pyloromyotomy for a congenital pyloric stenosis is described in Chapter 18.

Gastrojejunostomy

A gastrojejunostomy involves the anastomosis of a loop of proximal jejunum to the stomach. This may be used as a drainage procedure in conjunction with a vagotomy or as a bypass for a gastric outlet or duodenal obstruction. The most frequent causes of obstruction are malignancy and chronic peptic ulcer disease and in these patients preoperative correction of hyponatraemia and hypoalbuminaemia has been shown to correlate with a reduction in morbidity and mortality.

The anastomosis is a side-to-side anastomosis between a dependent portion of the stomach and the proximal jejunum. The opening in the stomach can be horizontal, oblique or vertical, and according to the direction of the jejunal loop may be described as isoperistaltic or antiperistaltic. There appears to be no specific advantage of one configuration over another. The anastomosis can be in front of the transverse colon, when it is described as an anterior or antecolic gastroenterostomy, or behind the transverse colon, when it is described as a posterior or retrocolic gastroenterostomy (Figure 17.13). When the distal stomach and pylorus have been excised, and an anastomosis to the duodenum as a Billroth I reconstruction is not possible, a loop of jejunum is brought up for a Billroth II reconstruction. This anastomosis is in essence another form of gastroenterostomy.

OPEN GASTROENTEROSTOMY

A *posterior (retrocolic) anastomosis* is often favoured as it may offer better function. The omentum and transverse colon are lifted up and the duodenojejunal flexure and the first jejunal loop are identified. The anastomosis can usually be made to the segment between 10 and 20 cm from the duodenojejunal flexure, but it must reach the stomach without tension. A window is created in the transverse mesocolon through an avascular area, usually to the left of the middle colic vessels, taking care not to damage them. A dependent part of the gastric antrum is then brought through the mesocolic window using atraumatic Babcock forceps (Figure 17.13a).

In recent years there has been a shift towards the use of intestinal stapling devices for the anastomoses as they offer a reduction in operative time. However, for many surgeons the cost implications of a stapled anastomosis are a major consideration. Irrespective of the technique used, the principles that ensure a successful outcome include a good vascular supply to the segments being approximated, no distal obstruction and a tension-free anastomosis. These principles were explored more fully in Chapter 14. The classic two-layer, hand-sewn, side-to-side anastomosis suitable for a gastroenterostomy was described in detail in Chapter 14, and illustrated in Figures 14.11 and 14.12 (pp. 236 and 237). The alternative stapled anastomosis using a linear cutting stapling device is also described in Chapter 14. In a retrocolic anastomosis, whether a stapled or a hand-sewn technique is used, the margins of the defect in the mesocolon are sutured to the stomach in order to prevent herniation of the small intestine through the mesocolic window (Stammers' hernia).

In obese patients with a short thick mesocolon and a relatively fixed stomach, a conventional hand-sewn posterior gastroenterostomy can prove difficult. In this event, access into the lesser sac by separating the greater omentum from the transverse colon allows the selected loop of jejunum to be drawn upwards through a window in the transverse mesocolon. Anastomotic clamps can then be applied and the anastomosis performed with relative ease above the transverse colon. On completion, the anastomosis is drawn down through the window in the mesocolon, and the edges of the mesocolic window are sutured to the stomach. The final alignment of the anastomosis is thus identical to that illustrated in Figure 17.13d.

LAPAROSCOPIC GASTROENTEROSTOMY

The position of the ports varies with the surgeon's preference but in general, an initial umbilical port will be chosen followed by a 10-mm working port in the left hypochondrium and a 5-mm port at the xyphisternum. Additional working ports can be inserted if required at any stage. An *antecolic anastomosis* is often favoured laparoscopically for technical reasons.

The segment of jejunum to be used is identified and stay sutures are then inserted. A straight needle is inserted percutaneously and directed through the jejunum and the stomach, close to the intended gastrotomy and enterotomy sites. The needle is then exteriorised again under direct vision.This suture approximates the stomach and duodenum. A second stay suture may be inserted in a similar fashion just beyond the far end of the intended anastomosis (Figure 17.14a). These sutures provide control of the segments being united and also allow them to be elevated, thereby improving access and reducing spillage. The stomach and the antimesenteric border of the jejunum are then opened using laparoscopic diathermy scissors or an ultrasonic scalpel (Figure 17.14a). A Babcock forceps, inserted through the 5-mm port, provides control and the laparoscopic scissors are inserted through the 10-mm port. The length of these enterotomies should only be sufficient to accommodate the stapling device. A laparoscopic intestinal stapling device is then inserted through the 10-mm port and a limb is manoeuvred through each of the enterotomies. The device is then closed and fired (Figure 17.14b). It is important to check that the hilt of the

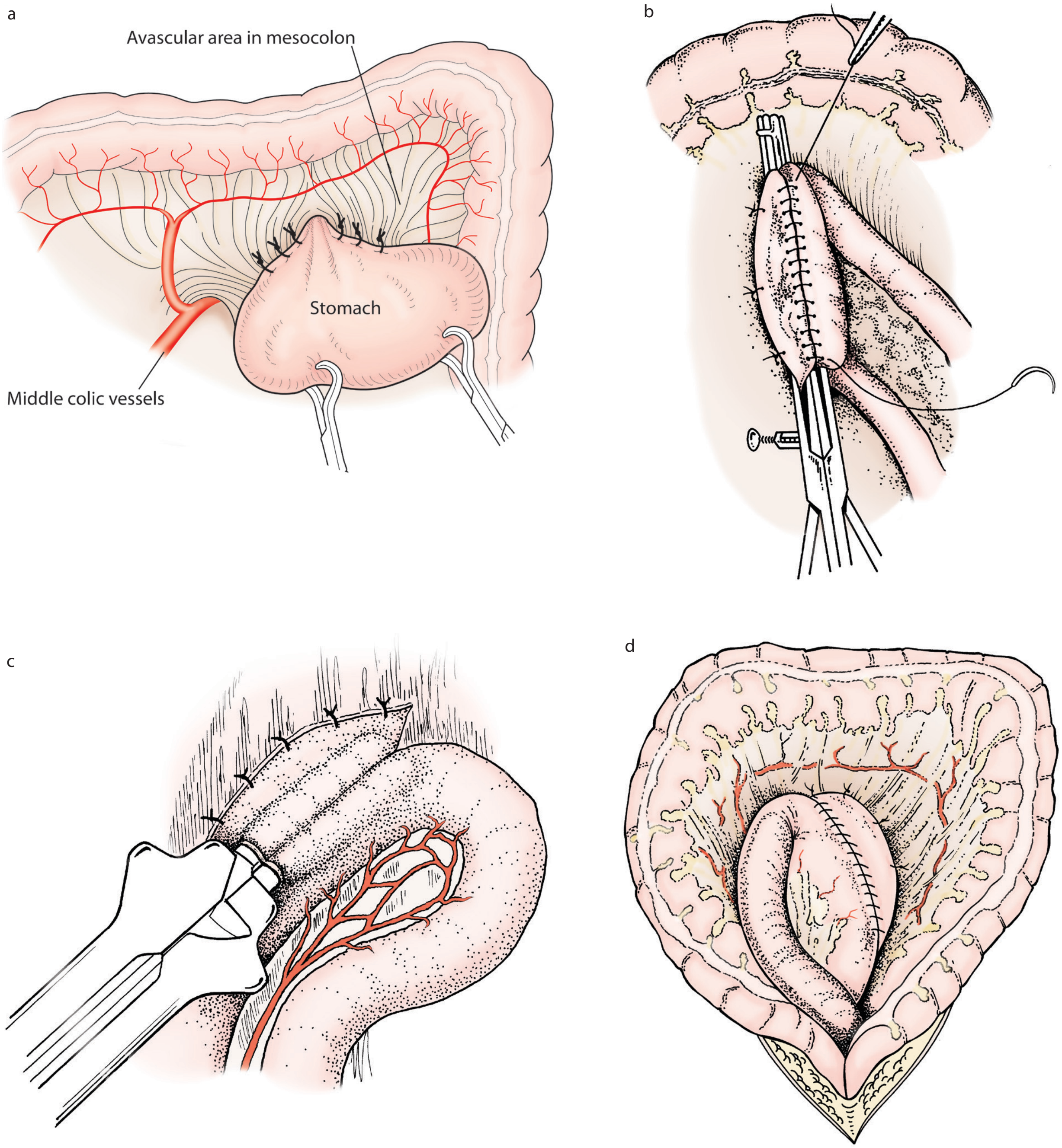

Figure 17.13 *Retrocolic gastroenterostomy. (a) Gentle manipulation of the stomach through the window in the transverse mesocolon using atraumatic Babcock forceps. (b) The classical hand-sewn anastomosis. (c) The alternative stapled anastomosis. (d) A completed oblique isoperistaltic anastomosis lying below the transverse mesocolon; the mesocolic window has been closed.*

endoscopic gastrointestinal anastomotic stapling device is snug to the enterotomies before firing to ensure an adequate opening. The enterotomies themselves may be closed using a second firing of the device or by laparoscopic suturing. Care must be taken to avoid narrowing the opening at this stage. The stay sutures are removed and the stomach insufflated via the nasogastric tube to look for any leakage. The greater omentum can be placed over the anastomosis. There is usually no indication for a drain.

Gastroparesis

Gastric emptying after a gastroenterostomy is sometimes very delayed (see Gastroparesis in Chapter 18). With long-standing gastric outlet obstruction, an element of gastric atony develops and there may also be obstruction of the stoma from oedema. If this complication has been anticipated and a fine-bore transanastomotic tube inserted (see Chapter 12), enteral feeding can be maintained while awaiting resolution.

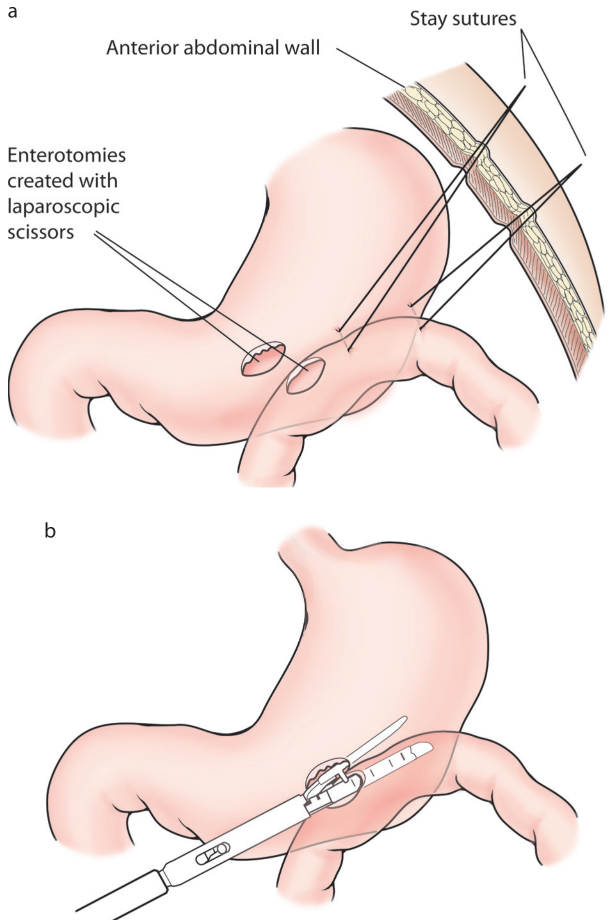

Figure 17.14 *Laparoscopic gastrojejunostomy. (a) Stay sutures are inserted prior to the creation of the enterotomies. (b) Insertion of the endoscopic gastrointestinal stapling device through the enterotomy openings.*

ROUX LOOP

An alternative form of gastroenterostomy is the anastomosis of a Roux-en-Y loop of jejunum to the stomach, as an end-to-side anastomosis rather than the classical side-to-side gastroenterostomy. A Roux loop has the advantage of less biliary reflux. The formation of a Roux loop is described in Chapter 22. This is a particularly appropriate method of gastric drainage when there is only a small residual proximal stomach remnant, whether after gastric resection for cancer or a gastric exclusion operation for morbid obesity. A Roux loop is also used in the reconstruction after a Whipple's pancreatectomy (see Chapter 20).

GASTRECTOMY

Gastrectomies are classified in three different ways which, at the outset, can be confusing:

1. Gastrectomies can be classified according to the amount of stomach that is excised: a total or a partial gastrectomy. A partial gastrectomy can be a proximal partial gastrectomy, when it is usually combined with a distal oesophagectomy. More often, a partial gastrectomy is a distal partial gastrectomy, and this can be subdivided into an antrectomy, in which only the gastric antrum is removed, a standard partial gastrectomy, in which around half the stomach is excised, and a subtotal gastrectomy.
2. As an alternative, gastrectomies can be classified according to the method of reconstruction. After a distal partial gastrectomy, the remaining stomach can be anastomosed to the mobilised duodenum, and is described as a Billroth I gastrectomy (Figure 17.15a). If instead the duodenum is closed and the first loop of jejunum is brought up for the anastomosis, this is described as a Billroth II gastrectomy (also referred to as a Polya gastrectomy) (Figure 17.15b). Although the two operations were initially considered slightly different, the names are now usually used synonymously. A further alternative reconstruction is with a Roux-en-Y loop, as illustrated in Figure 17.15c.
3. The third classification is related to the radicality of the lymphadenectomy that is combined with the gastrectomy. A D0 gastrectomy is an excision inside the gastric and gastroepiploic arcades and no lymph nodes are removed with the stomach, a D1 gastrectomy includes only the N1 nodes, and a D2 gastrectomy also includes the N2 nodes.

All gastrectomies can be performed by either an open or a laparoscopic approach. Initially, a laparoscopic approach was considered to have limitations when an extensive lymphadenectomy was planned, but increasingly these technical difficulties have been overcome with improvements in both equipment and technical skill. The classic gastrectomies are described first for open surgery and then the modifications and challenges discussed when undertaken laparoscopically.

After any gastrectomy, postoperative management is similar. The nasogastric tube is traditionally left *in situ* until gastric function returns. It is used to aspirate gastric secretions and will also help to detect postoperative intraluminal bleeding. The possibility of extending enhanced recovery programme philosophy to gastric surgery is being explored.[6] However, gastric emptying can be slow to recover, either from gastric paresis or because of oedema at the site of the anastomosis. If this is anticipated, the intraoperative insertion of a feeding jejunostomy tube will secure enteral access for feeding (see Chapter 12 and Figure 12.2, p. 205).

Billroth I gastrectomy for benign disease

Professor Hans Theodore Billroth described his first gastric resection for malignancy in 1881. A Billroth I gastrectomy involves removal of a distal gastric segment, followed by primary anastomosis with preservation of duodenal integrity. Nowadays, the classic Billroth I gastrectomy is an operation that is almost entirely reserved for benign pathology, as in the standard operation only a very limited lymphadenectomy is

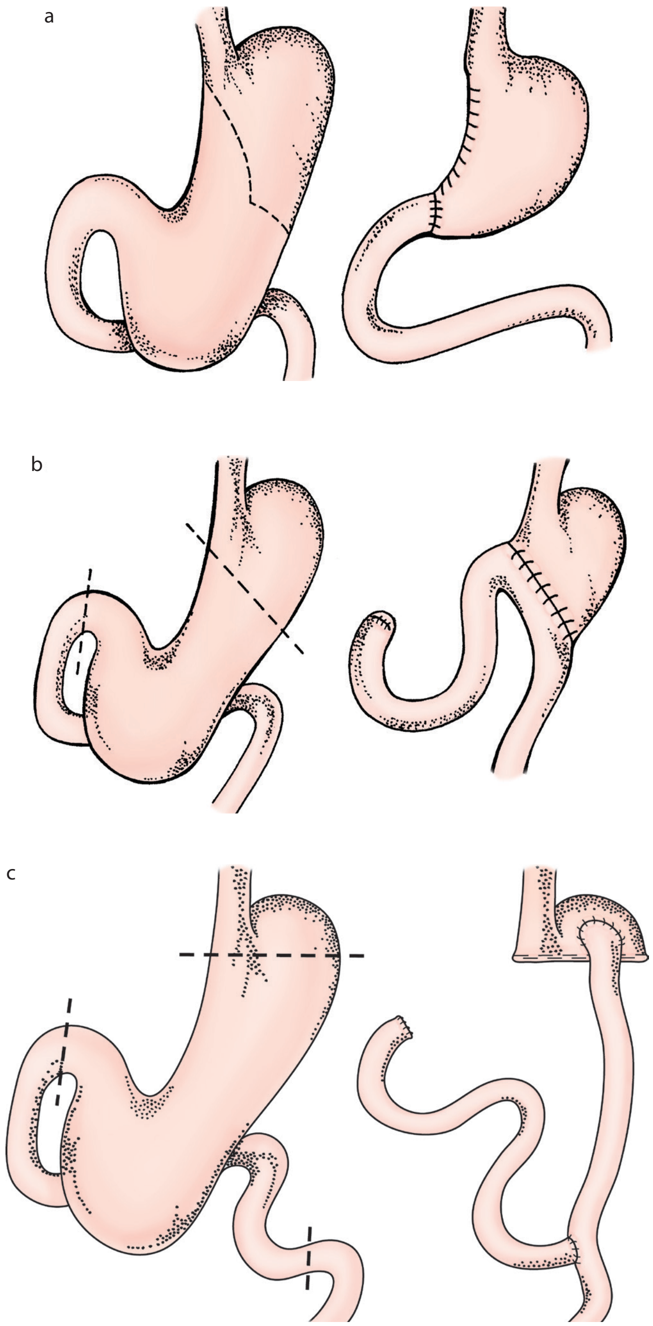

Figure 17.15 *Diagrammatic representation of modes of reconstruction after partial gastrectomy. (a) Billroth I. (b) Billroth II or Polya. (c) Roux-en-Y loop.*

achieved. Surprisingly, however, this method of reconstruction is still possible after a radical partial gastrectomy and lymphadenectomy as there has been extensive mobilisation. The advantage of a Billroth I gastrectomy over a Billroth II (Polya) procedure is the maintenance of the physiological and anatomical gastroduodenal pathway. Thus, it offers a lower incidence of post-gastrectomy syndromes, minimal disturbance of pancreatic function and a possible lower incidence of late development of carcinoma in the stomach remnant.

Operative procedure

The abdomen is usually opened by a midline laparotomy incision, although some surgeons prefer a right paramedian or a bilateral subcostal incision. A Balfour retractor should provide adequate access, but for very obese patients Goligher-type bars or an Omnitract retractor system may improve access. The stomach and greater omentum are drawn out of the wound and retracted inferiorly by the assistant.

Starting close to the pylorus, the greater omentum is detached from the stomach. With benign disease the plane of dissection may be between the stomach and the gastroepiploic vessels, with ligation of only the gastric branches of the arcade (Figure 17.16a). Preservation of the gastroepiploic vessels ensures the viability of the greater omentum and may also provide additional blood supply beyond the limits of the gastric resection, ensuring a healthy anastomosis. Avascular adhesions between the stomach and pancreas are divided. Occasionally, a posterior gastric ulcer may extend into the pancreas, and this requires careful dissection, ensuring haemostasis.

The lesser omentum is then incised in its avascular plane outside the gastric arcade, allowing identification of the right gastric artery. The right gastric artery may be represented by several vessels rather than a single trunk, whereas the left gastric artery is almost always represented by a single, usually substantial, vessel. The right gastric artery is ligated and divided. Division of the lesser omentum continues parallel with the lesser curve. In benign disease the descending branch of the left gastric artery can usually be preserved and ligated after it has given its first branches to the lesser curve, so that the gastric remnant receives additional blood supply from the proximal portion of the left gastric artery. The stomach is lifted forwards and the inferior border of the first part of the duodenum is separated from the pancreas, carefully dissecting and ligating small vessels.

Kocherisation of the duodenum will facilitate the anastomosis and reduce tension at the suture line. The duodenum beyond the proposed resection line must be inspected to ensure that it is healthy and of sufficient calibre for the gastroduodenal anastomosis. The duodenum is then divided between two non-crushing clamps (Figure 17.16a) or with a linear cutting stapling device.

The line for the gastric resection is determined and the stomach divided with a linear stapler (Figure 17.16b). This may require firing twice to divide the whole way across. Many surgeons elect to oversew the staple line in order to ensure haemostasis. A clamp is then applied at an angle to the original stapled closure at the greater curve and a segment removed to correspond to the duodenal lumen (Figure 17.16c). When stapling devices are unavailable these two manoeuvres can be performed by applying clamps at an angle to each other. The stomach is divided close to the clamps with a scalpel. The lower clamp encloses a portion of the gastric lumen suitable in size for the anastomosis, while the transected stomach held in the upper clamp is closed in two layers.

Provided that the greater curve has been adequately mobilised, the gastric remnant can be brought to the duodenum

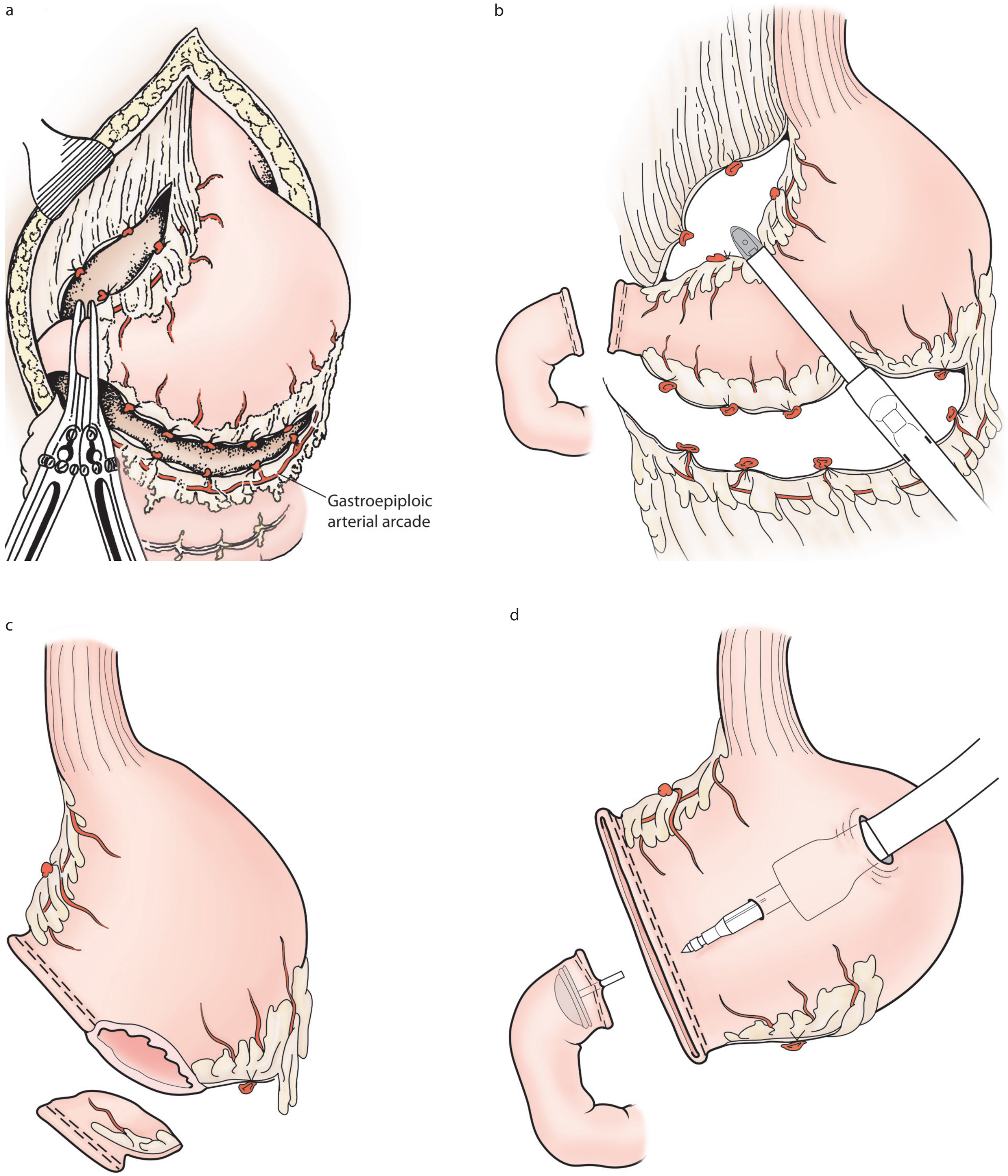

Figure 17.16 *Billroth I gastrectomy. (a) The greater curve has been mobilised inside the gastroepiploic arcade and the lesser curve outside the gastric arcade. The duodenum is divided with a stapling device or between clamps. (b) The stomach is divided with a linear cutting stapling device. (c) A wedge at the greater curve is excised for the anastomosis. (d) A stapled alternative to the traditional hand-sewn Billroth I anastomosis.*

and anastomosed without tension. Stay sutures are inserted into the tissues that are to be approximated. Either a single- or a two-layer anastomotic technique is suitable. When a two-layer technique is used, the outer layer usually consists of interrupted seromuscular sutures, and this posterior outer layer is placed first. The posterior wall is then completed by an all-layer continuous suture. This suture is continued forwards as the all-layer suture of the anterior aspect of the anastomosis, before the final anterior interrupted seromuscular sutures are placed. In a one-layer technique only the continuous all-layer suture is employed, and the outer interrupted seromuscular sutures are omitted. Particular care must be taken with suture placement at the 'angle of sorrow', the 'lesser curve' of the anastomosis (i.e. the junction between the part of the stomach that has been closed and the part used for the anastomosis), as this is the area that is especially prone to leakage.

Alternatively, the anastomosis may be performed using an end-to-end anastomotic circular stapler (Figure 17.16d). The stapler head is inserted into the duodenum and secured using a purse-string suture. The stapler is inserted into the stomach through a small incision at a more proximal site. The spike of the locking device is brought out distally, avoiding the staple or suture line of the distal stomach. The two portions of the stapling device are locked into place, approximated and the staples fired. The gastrotomy used to introduce the circular stapler is then closed by elevating it between Babcock forceps and firing a linear stapler. Alternatively, the defect can be sutured. To confirm duodenal integrity some saline is instilled around the anastomotic site, a non-crushing clamp is placed distal to the duodenum and the duodenum inflated with air via the nasogastric tube. An absence of bubbles helps to confirm integrity.

Billroth II (Polya) gastrectomy for benign disease

Many different types and variations of this gastrectomy have been described, but a Billroth II gastrectomy essentially involves a distal gastric resection, with closure of the duodenal stump, and restoration of intestinal continuity by a gastrojejunostomy. The technique was first described in 1911. Since then surgeons have opted for longer loops of jejunum, with some favouring an antecolic anastomosis and others a retrocolic anastomosis. While the Billroth II reconstruction is associated with a higher incidence of reflux gastritis and dumping syndrome than Billroth I, it offers an alternative in any situation where a Billroth I is not technically possible owing to excess tension at the anastomotic site.

Operative procedure

The initial steps for a Billroth II gastrectomy are similar to that described for a Billroth I gastrectomy. However, a smaller gastric remnant is often left, as it need not reach the duodenum for reconstruction, and the descending branches of the left gastric vessels are seldom preserved. The vessels must be identified and ligated with care. At this stage, the zone of demarcation between ischaemic and well perfused stomach acts as a guide when deciding the level for the gastric transection.

The duodenum is then Kocherised. The stomach is lifted forwards, allowing the inferior border of the first part of the duodenum to be separated from the underlying pancreas. Caution is advised at this stage or troublesome bleeding can ensue. Occasionally, the duodenum may be adherent to the pancreas secondary to an ulcer, and must be dissected free under direct vision. Once the inferior portion of the first part of the duodenum is freed, a linear stapling device is passed posterior to the duodenum and the duodenum transected. The rows of staples on the duodenal stump may then be reinforced by a continuous absorbable seromuscular suture (e.g. 3/0 PDS®), which buries the suture line. Surgeons who do not have access to stapling devices will have to use one of the traditional techniques for duodenal closure. The duodenum can be divided between two straight crushing clamps and the distal end closed with two layers of absorbable sutures. This can be difficult when there is inflammation or scarring, and the first layer of sutures must be placed before the clamp is removed. The old '*sewing machine*' stitch for the first layer may be useful when the duodenal stump is short and difficult to invaginate (Figure 17.17). Occasionally, when there is a very large duodenal ulcer, it is not possible to close the duodenal stump. This difficulty is discussed further in Chapter 18, with two solutions illustrated in Figure 18.4 (p. 300).

Transection of the duodenum allows the stomach to be elevated, displaying the left gastric artery as it reaches the lesser curve just below the oesophagogastric junction. Both the lesser and greater curves should be free of omentum at the site selected for transection. The next stage depends on whether stapling devices are to be used for the transection and for the anastomosis. There are still several alternatives with stapling devices. For example, the proximal stomach can be divided between a distal clamp and a proximal linear horizontal stapling device (see Figure 14.13, p. 237) or it can be divided and both ends sealed using a linear cutting stapling device, as shown in Figure 17.16b. There may be some benefit in using tissue reinforcement staple devices to reduce the risk

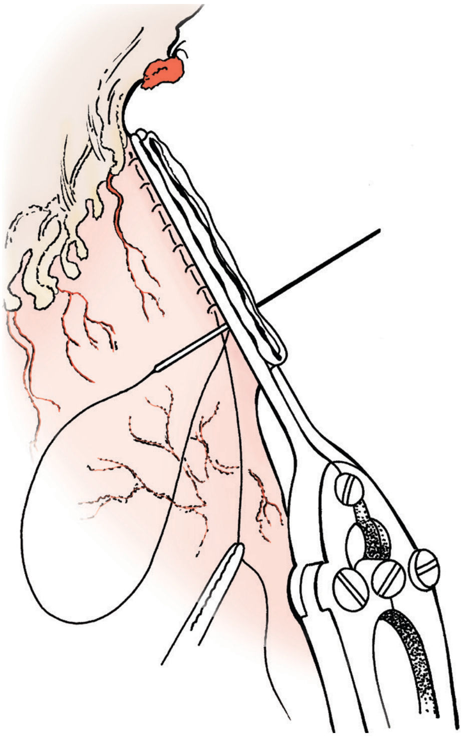

Figure 17.17 *The 'sewing machine' stitch can still be a useful suture for closure of a difficult duodenal stump when no stapling devices are available.*

of postoperative bleeding and leaks (see Chapter 14). The proximal loop of jejunum is then brought up through the transverse mesocolon, and a gastrojejunostomy can be fashioned using an intestinal stapling device as described in Chapter 14 (Figure 14.14, p. 237). Alternatively, a portion of the staple line at the greater curve can be trimmed and a hand-sewn anastomosis constructed.

When no stapling devices are employed, the stomach and duodenum are divided between clamps. It is customary to insert the posterior seromuscular suture before the stomach is transected (Figure 17.18a). A crushing clamp is then applied to the stomach 1 cm distal to the suture line, and the stomach is divided with a scalpel, flush along the underside of the crushing clamp. A hand-sewn anastomosis is then performed using locking twin clamps in a similar fashion to that described for a standard gastroenterostomy in Chapter 14. If the whole width of the transected stomach is used for the anastomosis, this results in a very wide outflow channel from the stomach, with a probable increased incidence of 'dumping'. A narrower stoma can be created by restricting the jejunal incision to 3–4 cm and using only that portion of stomach that is opposite this incision for the anastomosis. The remainder of the gastric transection is closed (Fig. 17.18b). After completion of the gastroenterostomy the anastomosis is drawn through the defect in the transverse mesocolon, the margins of which are attached to the wall of the gastric remnant with interrupted sutures placed about 1 cm above the suture line.

The Roux-en-Y gastrojejunostomy is an alternative technique to restore gastrointestinal continuity (see Chapter 22 and Figure 17.15c).

Laparoscopic gastrectomy for benign disease

The dissection for an N0 gastrectomy is emminently suitable for a laparoscopic operation. The position of port sites varies according to surgeon preference and patient body habitus but a 10-mm umbilical camera port and a 12-mm right hypochondrial port, in addition to a further 5-mm right hypochondrial port and two left hypochondrial ports, is a satisfactory arrangement. A steep head-up tilt improves access. The Harmonic® scalpel or Ligasure™ can be used for division of the gastric branches of the gastroepiploic vessel and division of the lesser omentum. The duodenum and stomach are divided with an endoscopic stapling device, but serial firing is necessary for the gastric transection. A Billroth II reconstruction is usually chosen for technical reasons. A window is formed in the transverse mesocolon to allow the loop of jejunum to be brought up for a retrocolic anastomosis, which is also performed with a stapling device in a similar fashion to that described for a laparoscopic gastroenterostomy above. After the anastomosis is performed, the stapler entry sites in the stomach and bowel wall may be closed with a single layer 3/0 Vicryl™ intracorporeal continuous suture; access seldom

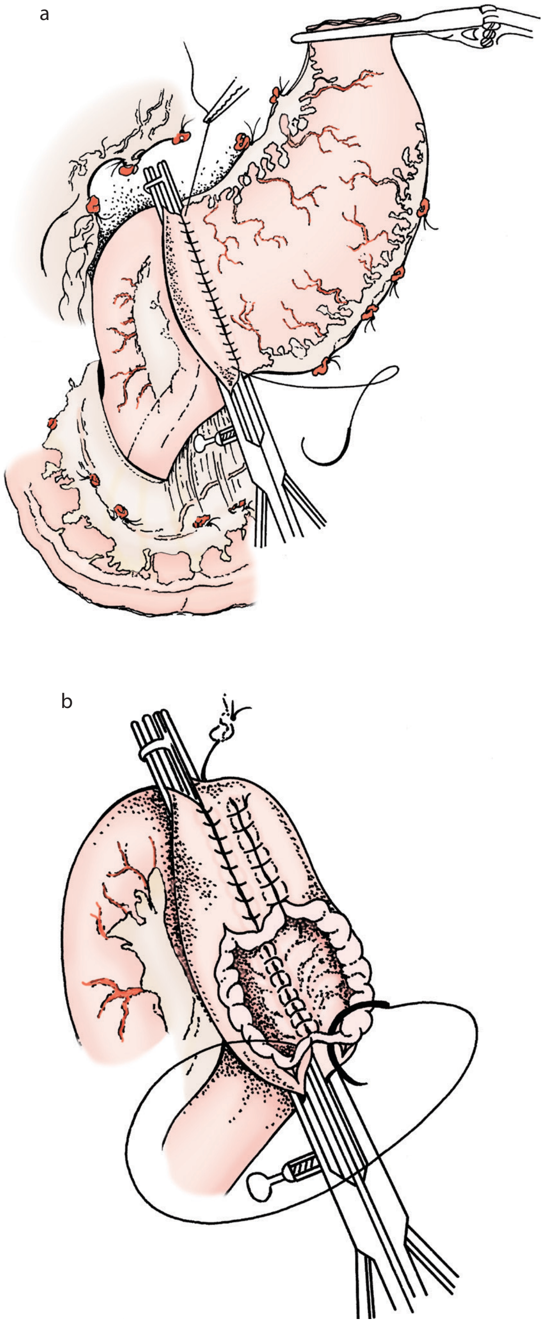

Figure 17.18 *A hand-sewn Billroth II (Polya) gastrectomy. (a) The duodenum has been divided between clamps and the stomach elevated so that the posterior seromuscular layer of the gastrojejunal anastomosis can be completed before the clamp is applied for the division of the stomach at the proximal limit of the gastric dissection. The full width of the stomach, and the jejunal loop, are held in twin occlusion clamps. (b) An appropriate-sized opening is made in the jejunal loop opposite the greater curve, and only this portion of the divided stomach is used for the anastomosis. The remainder of the transected stomach has been closed. The all-layer posterior section of the anastomosis has been completed and will be continued round anteriorly. The additional seromuscular suturing of the jejunal loop to stomach protects the anastomosis from distraction forces.*

allows this to be closed with a stapling device. The specimen may be extracted through the umbilical port using a laparoscopic bag.

GASTRECTOMIES FOR CANCER

The principle of operative intervention for gastric cancer is to achieve complete resection of the primary tumour with an *en bloc* regional lymphadenectomy. A total gastrectomy may be indicated when the extent or location of the primary tumour is such that adequate margins of resection (i.e. 4–6 cm) are not possible with a subtotal gastrectomy. This particularly occurs with proximal gastric tumours and extensive lesions, including linitis plastica. Macroscopic and microscopic clearance of the tumour (an R0 resection) should not be compromised by performing a subtotal gastrectomy when a total gastrectomy is indicated.

Gastric cancer has a high propensity for regional lymphatic spread. Traditionally in the UK, the gastrectomies for cancer included only the perigastric 1st tier nodes. However, in Japan the patterns of lymphatic spread were studied and surgeons pioneered more radical lymph node dissection.[1] These more extensive operations appeared to be associated with better long-term survival. Initially there was caution in the West, mainly related to concerns regarding greater operative morbidity and mortality. Pioneers did, however, encourage adoption of the technique in selected patients after visits to the Japanese cancer units[7] and the concept of the potential advantages of a more radical lymphadenectomy is now generally accepted (see also Chapter 18).

Not every patient is suitable for this surgery and preoperative assessment of a patient's cardiac, respiratory and nutritional status is particularly important when the lesion is in the gastric cardia or near the oesophagogastric junction, as radical excision may necessitate a thoracic incision. Preoperative staging (as discussed in Chapter 18) is also very important so that major surgery can be avoided in patients for whom it can offer no benefit.

D1 partial gastrectomy

This classic operation for distal gastric cancer only removes the 1st tier nodes (N1). The dissection differs from that described above for benign disease in that the dissection is such that the nodes are excised *en bloc* with the specimen. The greater curve nodes lie along the gastroepiploic vessels, which therefore have to be sacrificed and, subsequently, also the greater omentum. The initial dissection is therefore to open the plane between the transverse colon and the greater omentum. This plane can be difficult to dissect; time and care are essential to prevent injury to either the transverse colon or the middle colic vessels. The plane is often easiest to identify in its mid portion, with the omentum retracted up and the transverse colon retracted down. The plane can then be followed to left and right by sharp dissection. Although this embryological plane should be avascular, the occasional vessel does cross it and will need individual ligation.

Only a small gastric remnant is retained, inflenced by the knowledge of intramural invasion and the advisability of a 5 cm macroscopic margin. The left gastroepiploic vessels and the lower short gastric vessels are therefore divided, leaving only those short gastric vessels that provide essential blood supply to the gastric remnant. The lesser omentum is again opened in the avascular plane but as far away from the stomach as is practical. The left gastric artery is ligated and divided close to its origin from the coeliac axis. The right gastric and right gastroepiploic vessels should be ligated and divided as close to their origins as possible to include accompanying lymph nodes.

A Billroth II reconstruction is more commonly employed as, unless there has been extensive duodenal mobilisation, there may be concerns regarding tension on a Billroth 1 anastomosis.

D1 total gastrectomy

In this other classic operation for gastric cancer, the whole stomach is removed *en bloc* with the greater omentum. Traditionally, the spleen was also removed, but nowadays it is preserved if possible. Although some 2nd tier nodes were removed, especially if a splenectomy was performed, it is not a full D2 gastrectomy. The focus is on the more radical excision of the stomach rather than on a more complete nodal dissection. Reconstruction is with a Roux loop onto the oesophagus and, for adequate access, mobilisation and retraction of the left lobe of the liver by division of the left triangular ligament are recommended. The classic dissection differs from the partial gastrectomy described above by the early mobilisation of the spleen and ligation of the splenic pedicle, as described in Chapter 20. When the spleen and splenic vessels are preserved, the gastroepiploic and short gastric branches of the splenic vessels must be ligated individually. The oesophagojejunal anastomosis is described in the section on total D2 gastrectomy below.

D1 laparoscopic gastrectomy

A D1 gastrectomy can also be undertaken very satisfactorily by a laparoscopic approach. All the principles of the dissection are the same as in the open operation. Port sites and patient positioning are similar to those described for a D0 gastrectomy. The initial dissection to separate the greater omentum from the transverse colon is more challenging laparoscopically, especially if the omentum is bulky. All dissection can be undertaken with a Harmonic® scalpel, Ligasure™ or similar vessel sealing device. Careful dissection is required to the origins of the right gastric and right gastroepiploic vessels to retrieve lymph nodes in the vicinity. Ligasure™ or clips are usually satisfactory for securing these vessels, but many surgeons prefer the security of a stapled division of the right gastroepiploic pedicle. The left gastric artery is also usually divided with a stapling device. Division of the stomach and the Billroth II reconstruction are accomplished with a stapling device, as descibed above, and finally the specimen is retrieved in a cell-proof bag.

Laparoscopic approaches to the stomach require a considerable learning curve and mandate appropriate monitoring before they are embarked on in an independent surgical environment.

D2 subtotal gastrectomy

Subtotal gastrectomy with a D2 lymphadenectomy is particularly suitable for small gastric tumours involving the pylorus and distal third of the stomach. When macroscopic and microscopic clearance is obtained it provides equivalent survival rates compared with total gastrectomy, with a lower incidence of postoperative morbidity and mortality. The patient is left with a gastric remnant, which in theory reduces the potential for post-gastrectomy syndromes. Additionally, an anastomosis onto a well-vascularised stomach remnant is more secure than an anastomosis onto the oesophagus.

Operative access is obtained via an upper midline or bilateral subcostal 'roof-top' incision. A thorough abdominal examination is performed to determine the presence of metastatic disease, which may not have been identified with staging. Up to 20 per cent of gastric tumours are understaged in the preoperative assessment. Peritoneal deposits, liver metastases or the presence of metastatic disease in para-aortic lymph nodes precludes curative resection. A frozen-section examination may help differentiate metastatic disease from inflammatory reaction when enlarged nodes are encountered. If a curative procedure is not possible, the surgeon may still elect to proceed with a palliative resection for control of bleeding or the relief of outlet obstruction, in which case retrieval of lymph nodes is of much less importance.

The first steps are to mobilise the splenic and hepatic colonic flexures and to Kocherise the duodenum.[8] The greater omentum is detached from the transverse colon but in such a way as to enter the plane deep to the anterior leaf of the transverse mesocolon (Figure 17.19). The dissection continues in this plane, avoiding damage to the middle colic vessels or their branches. The omentum and the anterior leaf of the transverse mesocolon are removed *en bloc* with the stomach, thus keeping the lesser sac unopened at this stage. The dissection is continued on the right side until the right gastroepiploic vessels and subpyloric lymph nodes are identified. The right gastroepiploic vessels are carefully ligated and divided at their origins, and the nodes swept up into the tissue to be excised. The dissection is carried onto the pancreas, taking the overlying peritoneum/pancreatic capsule with the specimen. It is imperative to be in the correct plane. This plane on the surface of the pancreas is then followed laterally, where it will allow access to the left gastroepiploic and short gastric vessels. The left gastroepiploic vessels are divided, but the short gastrics must be carefully preserved as the only blood supply of the gastric remnant.

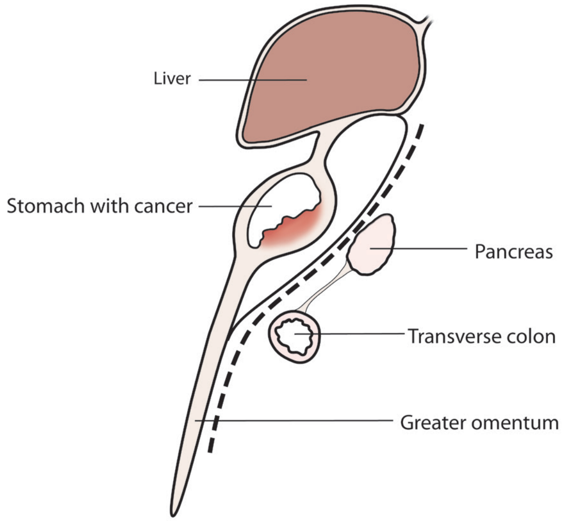

Figure 17.19 *Sagittal section showing the plane of dissection deep to the anterior layer of the transverse mesocolon and deep to the peritoneum of the posterior wall of the lesser sac.*

The omentum is then returned to the abdomen and the liver elevated with a retractor to expose the gastrohepatic ligament. This is divided at its left extremity to provide access to the oesophageal hiatus. The division of the peritoneal reflection onto the liver is then continued to the right, and the lesser sac is entered. In an antral carcinoma, consideration should be given as to whether portal dissection, with retrieval of station 12 lymph nodes, is indicated (see Chapter 18). When some selective additional 3rd tier nodes are removed, the operation may be referred to as a D2/3 gastrectomy. If these nodes are not to be dissected, the incision across the peritoneal reflection onto the liver stops to the left of the common bile duct and turns inferiorly towards the duodenum. When station 12 nodes are to be retrieved, the hepatoduodenal ligament is opened by continuation of the peritoneal incision into Calot's triangle, providing exposure of the common bile duct, hepatic artery and portal vein. The hepatic artery and its bifurcation are skeletonised, with retrieval of all lymph-bearing tissue. A tape around the hepatic artery, with slight traction, will provide exposure to the anterior portion of the portal vein. This dissection should yield a significant number of lymph nodes, which are excised in continuity with the main specimen. Whether the portal nodes are retrieved or not, the line of dissection comes down onto the common hepatic artery. The right gastric artery arising from it is identified and ligated near its origin.

The duodenum must be fully Kocherised to allow access to the retropancreatic and hepatoduodenal regions. This exposes the inferior vena cava and abdominal aorta, and also allows retrieval of right para-aortic and retropancreatic lymph nodes. The duodenum is then divided and closed.

This is most easily achieved with a linear cutting stapling device but, alternatively, it can be divided between two non-crushing clamps and the distal limb closed using a continuous 3/0 absorbable suture. Duodenal division provides access to the infrapyloric group of lymph nodes. Elevation and cephalad traction on the stomach expose the coeliac axis and the left gastric artery and the lymph nodes associated with these vessels. The left gastric artery is divided near its origin, with division of the left gastric vein along the superior border of the pancreas. Retrieval of tissue surrounding the left gastric artery, the hepatic artery and the coeliac trunk provides a high yield of lymph nodes. The ascending branch of the left gastric is divided just above the oesophagogastric junction so that the whole lesser curve arterial arcade and lymph nodes can be removed (see Figure 17.2). Stay sutures are placed at the greater and lesser curves and the stomach is transected, leaving a small gastric remnant with a blood supply from the remaining short gastric vessels. Once resection and lymphadenectomy are complete, reconstruction can be performed by a Billroth II or Roux loop technique. Surprisingly, a Billroth I reconstruction may also be an option after the extensive mobilisation that has been needed for the radical lymphadenectomy.

Total D2 gastrectomy with Roux-en-Y reconstruction

When potentially curative surgery is undertaken it is essential that the intramural spread of gastric cancer is remembered. Therefore, except in early gastric cancer, a total gastrectomy becomes necessary for all but antral tumours. Radical lymphadenectomy is of great importance, but is often not an exact D2 dissection in that depending on the location of the tumour, some 2nd tier nodes may be left *in situ* and some 3rd tier nodes removed. This is discussed in more detail in Chapter 18.

For a total gastrectomy, superior access will be required to the oesophageal hiatus and additional transhiatal dissection may be necessary for a proximal tumour. Goligher-type retractors or an Omni-Tract system are helpful, but a left thoracoabdominal incision may have to be considered for an extensive tumour involving the oesophagogastric junction. The initial assessment and dissection then follow the same principles as those for a subtotal D2 gastrectomy, as described above, until the dissection on the surface of the pancreas approaches the splenic hilum. Here all the short gastric vessels are divided in addition to the left gastroepiploic vessels.

The dissection then continues in a similar fashion to that described for the radical subtotal operation in order to retrieve lymph nodes associated with the gastric arcade, the hilum of the liver and the origins of the right gastric and gastroepiploic vessels. The dissection then returns to the greater curve and the remaining short gastric vessels are divided as close to the splenic hilum as is safe, and the lymph nodes taken *en bloc*. As discussed in Chapter 18, it is sometimes justifiable to include the spleen and even the pancreatic tail *en bloc* in the resected specimen, in which case the dissection proceeds lateral to the spleen to mobilise it. The splenic vessels, rather than the short gastric arteries, must then be ligated. When the stomach is fully mobilised and any remaining adhesions divided, stay sutures are inserted into the distal oesophagus to prevent its retraction after the stomach has been removed. It may be possible to apply a non-crushing clamp proximal to the oesophageal stay sutures. The oesophagus is then divided using either a scalpel or straight scissors. When the gastrectomy is for a cancer close to the cardia, it is desirable to include at least a short segment of oesophagus in the resected specimen, along with a cuff of diaphragm. When a longer segment of oesophagus needs to be resected, a thoracoabdominal approach or some other more formal access into the left chest is preferable.

A Roux-en-Y loop is brought up for reconstruction and the formation of an end-to-side oesophagojejunal anastomosis is recommended. This anastomosis is formed using a single layer of absorbable monofilament sutures inserted in an interrupted fashion (Figure 17.20a), but it can also be performed using a circular stapler. The head is carefully inserted into the oesophageal lumen, where it is secured with a purse-string suture. The main portion of the stapler is then inserted, via an enterotomy, into the jejunum (Figure 17.20b). The enterotomy is subsequently closed using a hand-sewn technique. There is also the option of using a longer segment of jejunum for the Roux loop, and making the end into a jejunal pouch using the linear stapler. This may improve the patient's postoperative capacity for food.[9]

Laparoscopic D2 gastrectomy

Laparoscopic D2 gastrectomy is highly specialised and concentrated in a few units. An advanced level of laparoscopic technique is required for the dissection and again any compromise in this will negate any short-term benefits of avoiding an open operation. Although initially pioneered in Asia, good results are now being obtained in the West in terms of node harvest. However, the technique laparoscopically has less emphasis on the *en bloc* resection of the tissue, the lesser sac is often entered early and the upper leaf of the transverse mesocolon left *in situ*. There are, therefore, theoretical disadvantages that lymphatic channels may be transgressed with resultant peritoneal contamination. However, as long-term results have not so far shown a worse prognosis, a laparoscopic approach has been accepted as an alternative operative strategy.[10]

OESOPHAGECTOMY

Oesophagectomy is performed almost exclusively for malignant disease. Benign conditions that occasionally warrant an oesophagectomy include long corrosive strictures and very

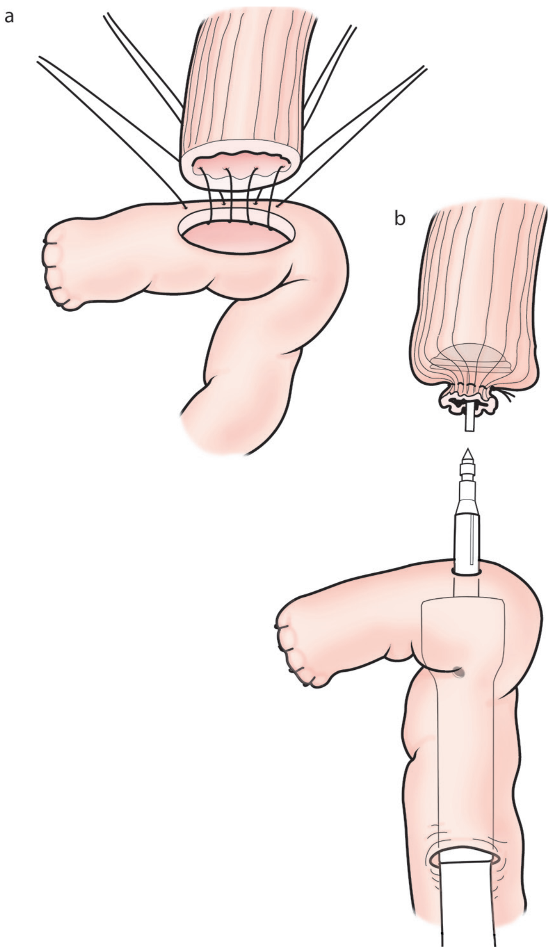

Figure 17.20 *Oesophagojejunal anastomoses after total gastrectomy. (a) Sutured. (b) Circular stapled through a separate enterotomy. Alternatively, the stapler can be inserted through the open end of the jejunal limb before it is closed. The stapled jejunal blind end should be oversewn.*

late presentation of achalasia. When considering operative intervention for oesophageal carcinoma, the choice of incision and procedure is determined by tumour type, location, operability and the patient's cardiorespiratory status. These are discussed in more depth in Chapter 18. The oesophagectomy may have to be combined with a partial or even a total gastrectomy to obtain adequate resection margins of a distal tumour. Similarly, a proximal oesophageal tumour may require the addition of a pharyngectomy to obtain local clearance (see Chapter 10). Three standard open approaches to oesophagectomy are described below: the transhiatal, the left thoracoabdominal and the three-stage operation. Many other techniques have been described, but most are modifications of the above. In recent years there has been continued movement towards less invasive approaches to oesophagectomy. The transhiatal dissection, thus sparing the patient the morbidity of a thoracoabdominal or a separate thoracotomy incision, was followed by combinations of laparoscopic and thoracoscopic minimally-invasive procedures. These all require a high level of expertise and are only practised in some specialist centres, and the indications and benefits of the different approaches have still to be clarified.[11]

Transhiatal oesophagectomy

Transhiatal oesophagectomy involves abdominal and cervical incisions only, thus avoiding a thoracotomy. The stomach, oesophagogastric junction and distal oesophagus are mobilised via the abdominal incision. The intrathoracic component of the oesophagus is freed distally through the diaphragmatic hiatus and proximally via the cervical incision. The resected oesophagus is then reconstructed using the gastric remnant or an intestinal loop as an oesophageal conduit. This is passed through the chest via the posterior mediastinum, allowing it to be anastomosed to the cervical oesophagus without tension.

Operative procedure

The patient is placed in a supine position with the neck elevated, supported in a head ring and turned to the right. Some surgeons favour turning the head to the left for a right cervical approach, and cite a lower incidence of recurrent laryngeal nerve injuries.

An upper midline laparotomy incision is made. A full laparotomy is performed to check for evidence of advanced disease, which might not have been apparent on imaging. This is particularly important in lower-third oesophageal cancers, which have a greater propensity to spread intra-abdominally. The presence of liver metastases, retroperitoneal lymph nodes or disseminated peritoneal disease means that no benefit is likely to be obtained by proceeding with oesophagectomy, and treatment should be aimed at palliative symptomatic relief.

The greater omentum is mobilised outside the right gastroepiploic vessels, which must be preserved as an arterial supply to the stomach remnant. The left gastroepiploic and short gastric vessels are then divided along the greater curve, taking care not to damage the gastric wall or spleen (Figure 17.21). The stomach is placed on stretch, allowing the gastrohepatic ligament to be incised. The right gastric artery is preserved, which, together with the right gastroepiploic artery, is the blood supply to the gastric remnant that will be used as the conduit. The left gastric vein and artery are identified and ligated near their origin.

When the stomach remnant is suitable to be used for the oesophageal conduit, the duodenum is Kocherised. The vagi will be divided during the oesophagectomy and therefore a pyloroplasty is performed to reduce delay in gastric emptying. An alternative favoured by some surgeons is a pyloromyotomy, which is thought to be associated with a lower incidence of bile reflux and alkaline gastritis.

The oesophageal hiatus is then mobilised, allowing a soft tubular drain to be passed around the oesophagogastric junction. If the tumour involves the hiatus, a cuff of diaphragm surrounding the tumour may be removed *en bloc* to ensure adequate margins of resection. Traction on the drain aids mobilisation of the distal oesophagus under direct vision and, with good retraction, dissection under direct vision can be performed up to the level of the carina. The surgeon's hand is then inserted through the diaphragmatic hiatus and, using blunt dissection and staying close to the oesophageal wall, the posterior oesophagus is separated from the prevertebral fascia. Anterior blunt dissection is then performed, again staying close to the oesophageal wall and avoiding cardiac displacement, which may give rise to arrhythmias and hypotension. Communication with the anaesthetist is crucial at this point. If any haemodynamic instability ensues, it will usually revert to normal if the hand is removed from the thorax, and all dissection must be halted until the patient has stabilised. The lateral oesophageal attachments must also be divided.

Attention is now turned to the neck. The cervical oesophagus is accessed by making an incision along the anterior border of the sternocleidomastoid (see Chapter 10). A low transverse cervical incision is a suitable alternative. The skin, subcutaneous tissue and platysma are incised. The carotid sheath is identified and retracted laterally and the trachea is retracted medially. The middle thyroid vein and inferior thyroid artery may need to be ligated and divided to avoid avulsion during dissection. It is imperative to avoid damaging the recurrent laryngeal nerve as it runs in the tracheo-oesophageal groove, and retractors should not be inserted blindly.

Posterior finger dissection will identify the prevertebral fascia and allow it to be separated from the posterior oesophageal wall. The recurrent laryngeal nerve is then identified and protected. Staying close to the oesophageal wall during anterior and right lateral dissection will reduce the risk of damage to the nerve and to the membranous posterior wall of the trachea. If a nasogastric tube is *in situ*, this will be helpful for this part of the dissection. A soft drain is inserted around the oesophagus. This aids further dissection and allows the cervical oesophagus to be elevated out of the incision. Usually, a combination of dissection from the abdominal and cervical incisions will free all attachments. Small oesophageal arteries that are avulsed during these manoeuvres usually retract and thrombose spontaneously. However, substantial mediastinal bleeding may signify damage to a larger artery or the azygos vein and warrants a thoracotomy for control of haemorrhage.

The level of the cervical oesophageal transection is then decided. Stay sutures are inserted proximal to this point into the lateral and medial walls. A latex drain is sutured to the oesophagus, distal to the line of transection. The nasogastric tube is then retracted proximal to the line of transection and the cervical oesophagus is divided cleanly using straight scissors, a scalpel or a stapling device. The oesophagus is then removed from below via the diaphragmatic hiatus. The latex drain sutured to the oesophagus is thus drawn through the posterior mediastinum. It is then detached from the oesophagus and left lying with one end at the cervical opening and one end in the abdomen, where it will serve as a guide to bring up the oesophageal conduit from the abdomen.

The stomach must now be prepared as a conduit to be drawn up into the chest. The highest point on the fundus is identified and will be used for the anastomosis. It is therefore possible to remove the oesophagogastric junction and the greater part of the lesser curve without reducing available length. This has the advantage of removing upper gastric drainage nodes to which a distal oesophageal cancer may spread (Figure 17.21). Division is usually undertaken using a stapling device, going from the lesser curve to the fundus to create a rotation gastroplasty, and the staple line of the gastric tube can be oversewn using an inverting stitch. The latex drain is now attached to the apex of the gastric conduit and used to guide the stomach up into the neck. This is aided by gentle manipulation of the stomach through the posterior mediastinum by the surgeon's hand. It is important to avoid gastric torsion.

The anastomosis can be created using a circular stapling device, introduced through a gastrotomy in a similar manner to that illustrated for a gastroduodenal stapled anastomosis in Figure 17.16d. However, a hand anastomosis may be preferred. A small anterior opening is made near the highest point of the fundus and the anastomosis fashioned with a single layer of interrupted sutures, using an absorbable suture material. The posterior layer of sutures is inserted first.

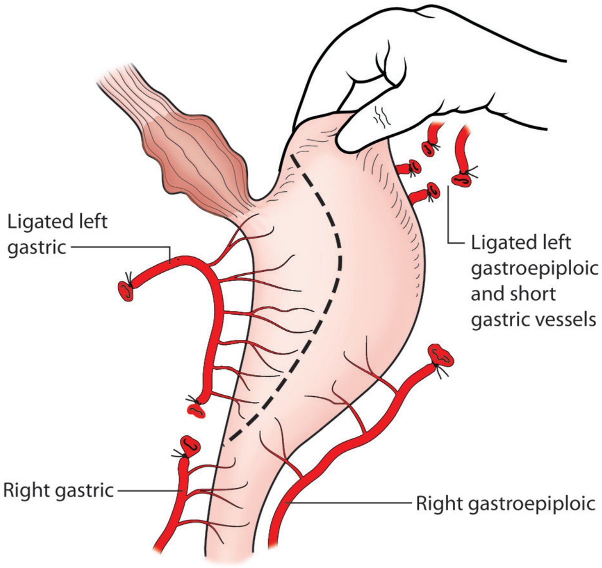

Figure 17.21 *Oesophagectomy: preparation of a gastric conduit. The blood supply for the conduit is from the right gastric and gastroepiploic arteries. The left gastric, the short gastric and the left gastroepiploic arteries have all been ligated. Gastric transection along the dotted line enables the cardia and the lesser curve and cardiac nodes to be removed* en bloc *with the tumour. The hand is holding the high point of the stomach, which will be used for the anastomosis.*

The nasogastric tube is then carefully advanced across the anastomotic line before closing the anterior layer. A small suction drain is placed close to the anastomosis prior to closing the neck incision.

Occasionally, the stomach cannot be used as a conduit. The tumour may have extended into the stomach, such that a gastrectomy was necessary, or the mobilised stomach may have an inadequate blood supply. Alternative conduits in this situation include colon and jejunum (see below).

Finally, a feeding jejunostomy tube can be inserted (see Chapter 12 and Figure 12.2, p. 205), as this allows enteral nutrition to be started within 24 hours. Usually, the nasogastric tube remains *in situ* for approximately 6 days. A water-soluble contrast swallow should confirm oesophageal integrity prior to the commencement of oral fluids.

Intraoperative complications

The surgeon should be competent to convert to thoracotomy if, during the procedure, there is an unforeseen intrathoracic complication. These complications can in the main be avoided by correct selection of patients for a transhiatal approach (as discussed in Chapter 18). Bleeding from the azygos vein or from oesophageal branches of the aorta may not be manageable without a lateral thoracotomy. Other potential complications include damage to the membranous posterior wall of the trachea. A tracheal tear represents a life-threatening complication. This may be a small tear, which is easily repaired at thoracotomy, or it may be extensive, where the tumour has abutted the trachea with the entire portion disrupted during the dissection. This latter variety is often fatal. When a tracheal tear occurs the endotracheal tube is deflated and advanced beyond the tear into the distal trachea or left main bronchus. This provides ventilatory control while the oesophagectomy is completed. An upper sternal split will provide adequate access to the trachea to determine if repair is possible (see Chapter 8).

The management of postoperative complications, including gastric remnant necrosis, cervical anastomotic leaks and chylothorax, is discussed in Chapter 18.

Thoracoabdominal oesophagectomy

This is a suitable approach for tumours involving the distal oesophagus, oesophagogastric junction and gastric cardia.

Operative procedure

The patient is placed in a right lateral decubitus position with the left arm flexed at 90 degrees to the body and placed in an arm-rest. It is a one-stage procedure that utilises a single incision with the initial transverse or oblique abdominal incision extended over the left chest (see Figure 13.15, p. 216). The operating table is rotated as the surgical field moves from abdomen to chest, or vice versa. The choice of intercostal space is decided on exploring the abdomen, and may be through the sixth, seventh or eighth space. The incision can extend to the edge of the erector spinae muscle, with the intercostal muscles incised using diathermy to achieve good haemostasis. The cartilage of the costal margin is divided, while the rib above or below the chosen space may be divided to provide greater access. Once the pleural cavity is entered a rib retractor is inserted.

The diaphragm is incised to the oesophageal hiatus in a circumferential manner to reduce the potential for damage to the phrenic nerve or its branches. A radial incision carries a significant risk of diaphragmatic paralysis. The inferior phrenic artery is ligated. Adhesions to the lung base and the lower part of the pulmonary ligament are divided so that the lung can be retracted upwards. The stomach is then mobilised as described previously, and the lower oesophagus is freed through a longitudinal incision in the parietal pleura between the aorta and the pericardium. The vagi are identified and divided. Encircling the distal oesophagus with a soft drain aids its subsequent dissection. Vessels should only be divided if this is essential for oesophageal mobilisation. The thoracic duct is ligated immediately above the diaphragm to prevent a chylothorax. Division of the diaphragm is now completed and the cuff is removed if this is required to ensure tumour clearance.

The thoracoabdominal approach is often chosen for more advanced oesophagogastric junction tumours where an oesophagectomy must be combined with a gastrectomy. However, the remaining stomach can often still be used as the oesophageal conduit, especially as it does not need as much length as it would for a cervical anastomosis. The division of the stomach and the formation of the gastric conduit are then undertaken in a similar manner to that described for the transhiatal operation. The anastomosis is performed beneath the aortic arch, and again this can be undertaken with a circular stapler or by a hand-sewn technique. If a total gastrectomy is necessary, reconstruction is usually with a Roux loop and an oesophagojejunal anastomosis.

The diaphragm is closed with interrupted absorbable sutures. At the diaphragmatic hiatus the gastric tube or other conduit is sutured to the diaphragmatic edge to prevent herniation. Two drains are inserted into the chest, with a straight 28-French drain directed to the apex and a 32-French angled drain directed towards the base, prior to left lung reinflation. Division of the costochondral cartilage may be a source of pain postoperatively. The divided edges must be closely approximated to prevent them rubbing together, with some surgeons favouring a miniplate attached by screws. Alternatively, 2 cm of costochondral cartilage is removed completely to prevent contact and friction.

Postoperative care is similar to that for transhiatal oesophagectomy, but the thoracic incision makes these patients more prone to respiratory complications, including atelectasis and pneumonia. Pain relief and physiotherapy are therefore extremely important.

Laparoscopic transhiatal resection

Gastric mobilisation is followed by transhiatal dissection of the oesophagus. Visualisation up to the level of the aortic arch is excellent and an essentially similar resection to the standard thoracoabdominal oesophagectomy can be achieved. However, as blunt finger dissection in the posterior mediastinum is not an option, laparoscopy cannot so readily replace laparotomy for the abdominal and thoracic dissection necessary for a transhiatal oesophagectomy with a cervical anastomosis.

Ivor Lewis and McKeown oesophagectomies

The Ivor Lewis oesophagectomy is a two-stage procedure with a laparotomy and a right thoracotomy.[12] The advantages over the thoracoabdominal approach are avoidance of the troublesome wound crossing the costal margin and improved access to the thoracic oesophagus. The three-stage approach, as described by McKeown, consists of cervical, abdominal and right thoracotomy incisions.[13] Thus, it combines the excellent laparotomy and right thoracotomy exposure provided by the Ivor Lewis approach with the safety of a cervical anastomosis. A minimally-invasive Ivor Lewis oesophagectomy is now yet another alternative.[14]

ABDOMINAL COMPONENT

The abdominal component is performed first, through a midline laparotomy incision, and this allows intra-abdominal spread, which would preclude a curative resection, to be excluded before proceeding further. If the tumour is still judged to be resectable, the stomach is mobilised with preservation of the right gastroepiploic and right gastric arteries. The duodenum is Kocherised and a pyloroplasty or pyloromyotomy performed, as described for transhiatal oesophagectomy. The oesophageal hiatus is mobilised to provide access to the distal oesophagus and the hiatal opening enlarged as required. Once the stomach is adequately mobilised and freed of attachments, it is then partially delivered into the chest cavity. A feeding jejunostomy tube can be inserted at this stage and sutured to the anterior abdominal wall. The abdomen is closed.

THORACIC COMPONENT

The patient is then placed in a left lateral position, which allows a right posterolateral thoracotomy to be performed through the fourth or fifth intercostal space (as described in Chapter 8). The double-lumen tube allows the right lung to be collapsed, with ventilation maintained through one-lung anaesthesia.

The inferior pulmonary ligament is divided and the lung gently retracted by the assistant. The mediastinal pleura overlying the oesophagus is divided and the azygos vein identified and double-ligated before division. Dissection continues to free the oesophagus and all the para-oesophageal lymph nodes are included with the resected specimen. Oesophageal arterial branches are divided between clips. During superior dissection care must be taken to avoid damaging the recurrent laryngeal nerve. Many surgeons routinely identify and ligate the thoracic duct immediately above the diaphragm, on the right lateral aspect of the descending aorta, to reduce the subsequent incidence of chylothorax. Knowledge of the course of the duct and its potential anatomical variations is important if damage is to be avoided intraoperatively. The thoracic duct is the principal lymphatic drainage system. It commences as the cisterna chyli, in the midline, at the level of the twelfth thoracic vertebra to the right of the aorta. It passes through the diaphragmatic hiatus into the chest and ascends on the right side of the thoracic spine until the level of the fourth or fifth thoracic vertebra, where it crosses posterior to the aorta to ascend on the left side of the oesophagus. In the root of the neck, just above the level of the clavicle, it arches forwards and passes anterior to the left subclavian and common carotid arteries, eventually emptying into the left subclavian vein near its junction with the left internal jugular vein. The thoracic duct is thus particularly vulnerable to injury when the supra-aortic oesophagus is removed or when there is dissection around the right side of the aorta, as when the para-aortic mediastinal nodes are retrieved. Although some surgeons recommend routine ligation of the thoracic duct during oesophagectomy, others are selective. Those who are selective are most likely to ligate the duct when a right thoracotomy is employed for an oesophagectomy that is to be combined with a more extensive intrathoracic lymphadenectomy.

Once the intrathoracic oesophagus has been adequately mobilised, the stomach is fully delivered into the chest via the hiatus. The distal resection limit is identified. The resected specimen may involve a variable portion of the proximal stomach, as discussed above. The stomach is divided so that it can be closed to form a tubular conduit, as described in the transhiatal oesophagectomy section.

CERVICAL COMPONENT

The cervical component is performed as described above for the transhiatal oesophagectomy. Once the oesophagus has been encircled by a soft drain, the distal dissection should not be too difficult provided that adequate mobilisation was performed at thoracotomy. The cervical oesophagus is divided and a latex drain attached to the distal portion. This is then pulled through from the thoracotomy opening. The latex drain is then attached to the gastric tube or alternative conduit and delivered into the neck avoiding torsion. The oesophagogastric anastomosis is then completed using a circular stapler or hand-sewn anastomosis, as previously described.

OESOPHAGEAL CONDUITS

Resection and replacement of the oesophagus have been a source of great challenge to surgeons. The preferred conduit is usually the stomach, provided that this reaches the proximal oesophagus with a good blood supply and without undue tension. If the patient has undergone a total gastrectomy, alternatives such as colonic interposition or jejunal grafts will have to be considered. The principles of the conduit are the restoration of gastrointestinal continuity with an adequate lumen and satisfactory function, while keeping the incidence of reflux, with the danger of aspiration, to a minimum.

STOMACH

The stomach is the conduit of choice for oesophageal replacement in almost all situations. Following oesophageal surgery, most patients have a significant gastric remnant of a size that will reach the proximal oesophagus. Kocherisation of the duodenum and division of the short gastric and left gastric vessels add to the length available for mobilisation. One advantage of the stomach over other grafts is the need for only a single anastomosis. There is, however, the risk of ischaemic necrosis at the apex of the gastric tube and, even in the absence of frank necrosis, a marginally adequate perfusion may contribute to anastomotic breakdown. A gastric conduit is associated in the long term with an increased risk of proximal oesophagitis and stricture.

COLON

The use of a colonic conduit involves three anastomoses, but the procedure is associated with a lower incidence of postoperative reflux symptoms, and patients may have an improved quality of life. Preoperative colonoscopy may be advisable to exclude underlying bowel disease. Right, transverse or left colon can be used as a colonic conduit, as discussed in Chapter 22. The right colon is more satisfactory, and if the ileocolic segment is used, there is little discrepancy between the lumen of the terminal ileum and the cervical anastomosis, ensuring a satisfactory end-to-end anastomosis. The terminal ileum and the distal transverse colon are divided and an ileocolic anastomosis constructed (see Figure 22.16, p. 392). The ileocolic vessels are divided and the conduit relies on its blood supply from the middle colic vessels and, variably, also from the right colic vessels, although the latter may have to be divided to provide sufficient mobility.

JEJUNAL ROUX LOOP

This is a satisfactory alternative conduit when a lower-third oesophagectomy has been combined with a total gastrectomy for a tumour of the cardia. A left thoracoabdominal incision has usually been employed and the anastomosis is below the aortic arch. This, however, is generally as high as it is possible to bring a Roux loop.

JEJUNAL INTERPOSITION

A segment of jejunum, with a suitable mesenteric vessel, is identified by mesenteric transillumination. The segment of jejunum, with its vascular supply still intact, is divided and the small bowel is anastomosed to restore intestinal continuity. The isolated segment can then be used as an isoperistaltic interposition graft. However, its blood supply will seldom allow it to be brought up for an anastomosis above the aortic arch. When the segment is needed at a higher level it must be used as a free graft, but this requires considerable expertise and microvascular experience. Jejunal interposition is therefore usually reserved for situations where other options are not possible or have failed. Its routine use is restricted to pharyngo-oesophageal replacement (see Chapter 10). As the small intestine does not tolerate prolonged periods of ischaemia, it is usual to isolate the graft but to leave it *in situ* until all other dissection is completed, the recipient vessels have been identified and everything is prepared for the microvascular reconstruction.

Route for the conduit

An oesophageal conduit can be brought up to the neck by the posterior mediastinal, the retrosternal or the subcutaneous route.

POSTERIOR MEDIASTINAL ROUTE

This is the route taken by the native oesophagus and is therefore preferred for a conduit in most circumstances. It is slightly shorter than the alternatives, and the proximal oesophagus and the conduit are well-aligned for the anastomosis. When the native oesophagus is removed transhiatally, a conduit can be tunnelled through the posterior mediastinum without a thoracotomy, as described above. However, this route may not be suitable when it is the site of dense adhesions. There may have been posterior mediastinal sepsis from a previous oesophageal perforation or failure of a previous conduit from ischaemic necrosis or anastomotic leakage. Corrosive damage, radiotherapy fibrosis and residual tumour can similarly exclude the posterior mediastinum.

RETROSTERNAL (ANTERIOR MEDIASTINAL) ROUTE

This is usually the preferred non-anatomical route where the posterior mediastinum is unsuitable. A midline retrosternal tunnel can be created by blunt finger dissection through abdominal and cervical incisions. A narrow, malleable intestinal retractor is then passed up the tunnel, keeping the tip immediately deep to the sternum. The conduit is then guided up to the cervical incision. The strap muscles are divided to allow the oesophageal substitute to pass to the oesophagus for an anastomosis. Unfortunately, the angulation of the conduit onto the cervical oesophagus and its abnormal anterior relationship to the trachea make swallowing feel unnatural and unpleasant.

SUBCUTANEOUS (PRESTERNAL) ROUTE

This route requires an even longer conduit than the retrosternal alternative and is nowadays used only occasionally. It may, however, avoid any possible respiratory compromise in a patient with very poor lung function. It may also have to be considered in a patient whose anterior mediastinum is unsafe because of adhesions between the heart and a median sternotomy scar from previous cardiac surgery.

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18

OPERATIVE MANAGEMENT OF UPPER GASTROINTESTINAL DISEASE

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UPPER GASTROINTESTINAL TRAUMA

The stomach is seldom injured by blunt abdominal trauma and the management of penetrating injuries to the stomach is usually straightforward. The stomach has good mobility and an excellent blood supply, which makes primary closure almost always successful. Oesophageal and duodenal injuries are, however, more common, and they are much more difficult to treat. The management of blunt and penetrating duodenal trauma was covered in Chapter 15. The oesophagus is seldom injured by blunt trauma, but it is vulnerable to injury in penetrating trauma to the neck. This is discussed in Chapter 10. Similarly, the intrathoracic or abdominal oesophagus can also be injured by penetrating trauma. However, most oesophageal injuries are iatrogenic, occurring during either endoscopy or surgery.

Oesophageal perforation

Oesophageal perforation is a relatively rare but life-threatening emergency. A high index of suspicion, coupled with prompt diagnosis and early intervention, is the key to achieving a successful outcome. Patients undergoing oesophageal stenting and dilatation of strictures are at particular risk, especially if there is an underlying oesophageal malignancy. When a perforation occurs it may be a through-and-through injury or, alternatively, a mucosal tear that becomes infected with subsequent perforation, leading to a delay between the time of endoscopy and the onset of symptoms. Post-endoscopic perforations are more common at the three areas of oesophageal narrowing: first at the cricopharyngeus (upper oesophageal sphincter), again at the level of the aortic arch/left main stem bronchus and finally at the oesophagogastric junction.

Boerhaave's syndrome, named after Herman Boerhaave, who first reported it in 1724, is a rupture of a normal oesophagus following an episode of retching. The first successful repair of a post-emetic oesophageal rupture was performed by Barrett in 1946.

The optimal management of an oesophageal perforation is dependent on the site of the perforation, the degree of contamination, the clinical state of the patient and the time interval between perforation and diagnosis. For many injuries, surgery to repair or at least drain the area of contamination is recommended, although a focused conservative approach is regaining respect. Conservative management consists of broad-spectrum antibiotics and either enteral feeding distal to the stomach or parenteral nutrition. In many cases a covered oesophageal stent is inserted endoscopically to seal the perforation. Endoscopic clipping of the tear is another strategy. Such patients should be in a specialist centre for assessment, as many patients are not suitable for this approach. Early referral is therefore mandatory so that the most appropriate management can be selected.[1] Close monitoring is also essential, as patients managed conservatively may require chest drain insertion for drainage of pleural effusions or image-guided drainage of mediastinal collections.

CERVICAL OESOPHAGEAL PERFORATION

The initial symptoms may be mild, but include neck pain, dysphagia and regurgitation of a bloody discharge. Palpation and movement of the thyroid cartilage will often elicit significant pain. The patient may quickly become systemically unwell, with the development of subcutaneous emphysema, mediastinitis and respiratory compromise. When suspected, the diagnosis can be confirmed by water-soluble contrast studies or by direct visualisation at endoscopy. Exploration of the cervical oesophagus should usually be performed under general anaesthesia, but for very sick patients local anaesthesia may be an option.

An oblique incision is made along the anterior border of the sternocleidomastoid on the side of the perforation. The carotid bundle is then retracted posteriorly and the middle thyroid vein divided. The presence of oedema and inflammatory reaction will direct the surgeon to the site of perforation. Upper endoscopy is a useful guide and also allows the performance of an insufflation test post repair to confirm oesophageal integrity. In an early clean perforation, it may be possible to close the perforation either with a single layer of absorbable sutures taking full-thickness bites or, alternatively, with a double layer consisting of an inner mucosal layer and an outer muscular layer. Copious washout is performed. Placement of a suction drain to the neck and superior mediastinum is important. Often, the tissues are too friable to allow a safe primary repair; it may then be more prudent to allow the tissue to heal by secondary intention, with a drain left adjacent to the perforation.

Postoperatively, a nasogastric tube is left *in situ* and the patient treated with broad-spectrum antibiotics. Oral intake is withheld until a contrast study, usually performed at around 7 days, confirms oesophageal integrity.

THORACIC OESOPHAGEAL PERFORATION

Contamination of the mediastinum results in a rapid onset of symptoms. Often, the first complaint is that of respiratory distress, with the development of a pleural effusion, usually on the left side. Cervical subcutaneous emphysema may be palpable. A chest X-ray may show mediastinal widening with pneumomediastinum, in addition to a pleural fluid collection or pneumothorax. Perforation can be confirmed by endoscopy, a water-soluble contrast study or a CT scan. A high index of suspicion is important if the diagnosis is to be established early, and this is important as prompt instigation of treatment is associated with a better outcome.

Surgical exploration as soon as the patient has been resuscitated is associated with the best outcome in most clinical situations. Lower oesophageal perforations are approached through the sixth or seventh intercostal space, on the side of the leak. If the perforation is recent, the contamination is minimal and there is no underlying oesophageal disease, it may be closed primarily. The entire length of the mucosal defect must be exposed and closed. Thus, the muscle will have to be divided proximally and distally at the limits of the perforation. The type of suture material and whether a one- or two-layer technique is used are generally matters of individual surgical preference. Closure is followed by extensive washout and the placement of chest drains for drainage of the mediastinum and pleura. If the perforation is less recent or there is extensive contamination, attempts at repair are unwise. Treatment instead consists of removal of all debris from the mediastinum, followed by lavage and drainage.

Occasionally, the thoracic oesophagus is extensively damaged and may necessitate an emergency oesophagectomy. However, this carries a high mortality and if the patient is critically ill, it may be prudent merely to drain the mediastinum and perform a cervical oesophagostomy. If the patient makes a satisfactory recovery, oesophageal continuity can be restored at a later stage.

If the patient has a perforated carcinoma, the overall prognosis is poor. Primary suturing is not an option, and healing will not occur with lavage and drainage. A palliative emergency oesophagectomy can be considered if the patient is well enough but, rather than performing heroic surgery, it may be better to adopt a cautious approach and insert a covered stent.

ABDOMINAL OESOPHAGEAL PERFORATION

Abdominal oesophageal perforations are almost exclusively iatrogenic and in most cases there is a high index of suspicion at the time of injury. In addition to endoscopic instrumentation, perforation of the abdominal oesophagus may occur in association with upper gastrointestinal procedures such as a Nissen fundoplication or a Heller's cardiomyotomy. When it is noted intraoperatively, it can be repaired immediately. This may sometimes require conversion from a laparoscopic to an open procedure. Abdominal perforations that present postoperatively usually require an upper midline laparotomy incision for peritoneal toilet and oesophageal repair, but they may also be explored laparoscopically. The repair can then be inspected with an endoscope and an insufflation test performed. As the oesophageal wall may be friable, it is important, if possible, to buttress the repair with the fundus of the stomach or with the omentum.

Caustic oesophageal injury

Management of caustic oesophageal injury depends on the severity of the caustic burn. Initially, treatment is supportive with analgesia, antibiotics and rehydration. Enteral feeding can be maintained if it is possible to establish a nasojejunal feeding tube; otherwise, parenteral feeding should be started. A partial-thickness burn of the oesophagus will heal, but stricture formation may ultimately be so severe that an oesophagectomy and reconstruction with an oesophageal conduit become inevitable. In more severe full-thickness damage to the oesophagus, the situation may be better managed by an early cervical oesophagostomy and a feeding jejunostomy. The severely damaged oesophagus may be safer left *in situ* until a delayed reconstruction is performed, often by an extra-anatomical route. In the most severe cases there may be oesophageal and gastric necrosis, with oesophageal perforation and mediastinitis. This makes an emergency oesophagogastrectomy the only option. A late reconstruction with a colonic conduit can then be undertaken if the patient survives.

MOTILITY DISORDERS OF THE OESOPHAGUS

Greater understanding of the pathophysiology of oesophageal motility disorders has contributed to improvements in diagnosis and treatment. The commonest disorders are achalasia, diffuse oesophageal spasm and nutcracker oesophagus. A variety of other non-specific oesophageal motility disorders are also recognised, but surgery only has an important role in the management of achalasia, where more than 90 per cent of patients can be offered a significant improvement in symptoms. Surgery can occasionally be considered in refractory diffuse oesophageal spasm, where a more extensive myotomy via a thoracic approach is required, but long-term results are disappointing.

Achalasia

Achalasia is characterised by loss of peristalsis, typically affecting the distal two-thirds of the oesophagus, in conjunction with failure of the lower oesophageal sphincter to relax in response to swallowing. A very similar achalasia can develop secondary to infection with the South American protozoal organism *Trypanosoma cruzi* (Chagas' disease).

PRESENTATION AND DIAGNOSIS

Patients complain of progressive dysphagia, retrosternal chest discomfort and regurgitation of food. In many cases there is a delay in diagnosis, with symptoms being attributed to cardiac or respiratory pathologies. Often there is a response to glyceryl trinitrate (GTN), which reduces the lower oesophageal sphincter pressure by its action as a smooth muscle relaxant, but unfortunately this symptomatic improvement is often attributed to anti-anginal effects, leading to further delays in diagnosis. With time, patients may develop proximal oesophageal dilatation with retention of large amounts of food residue. Delays in diagnosis increase the risk of complications such as development of oesophageal diverticulae, respiratory symptoms from aspiration and squamous cell carcinoma secondary to chronic inflammation.

All patients in whom achalasia is suspected require extensive evaluation including chest X-ray, barium swallow, upper endoscopy and manometry studies. Endoscopy is an important investigation to exclude 'pseudoachalasia'. This term is used to describe an appearance on barium swallow typical of achalasia despite an underlying pathology such as an oesophageal malignancy or a benign peptic stricture. Manometry is the 'gold standard' in the diagnosis of achalasia. In the typical case it will identify a raised lower oesophageal sphincter pressure (>25 mmHg) with loss of peristalsis in the body of the oesophagus.

The single strongest predictor of success following surgery is the preoperative lower oesophageal pressure reading. Higher values are associated with better outcomes.[2]

MANAGEMENT

Treatment options available include pharmacological measures, balloon dilatation and surgery. The mainstay of pharmacological therapy includes long-acting nitrates and calcium channel antagonists. Botulinum toxin injected under direct vision into the lower oesophageal sphincter will also decrease sphincter pressure, with over 90 per cent of patients obtaining symptomatic relief. Although the high pressures will return as the pharmacological effect of the injection wears off, this approach can be used as a diagnostic test in patients for whom the diagnosis is uncertain.

Pneumatic dilatation

Pneumatic dilatation is commonly used to disrupt the lower oesophageal sphincter and in most centres has replaced the use of progressive dilators. A balloon is placed across the oesophagogastric junction under fluoroscopic guidance and inflated to its maximum diameter. Given the risk of oesophageal perforation, all patients should have water-soluble contrast studies within 24 hours. Approximately 70 per cent of patients obtain symptomatic relief, but they may require a further procedure within 3 to 5 years. Pneumatic dilatation is a viable option in the initial treatment of achalasia and is useful in elderly patients and those who are high-risk candidates for surgical intervention. As a myotomy is technically more difficult following pneumatic dilatation, it is prudent to avoid a dilatation as first-line treatment in younger patients who are suitable for surgery, particularly as surgery has better long-term results.

Heller's cardiomyotomy

The transient response to pneumatic dilatation and pharmacological therapies gives surgery a prominent role in the long-term management of achalasia. This role has increased with the development of minimally-invasive approaches to the surgery. Both the surgeon and the patient should be aware that the dissection may be more difficult when there have been previous dilatations causing fibrosis. Heller's cardiomyotomy is described in Chapter 17. For a classical achalasia, surgery is usually performed using a laparoscopic approach. Because of the increased incidence of reflux symptoms, some surgeons routinely add an anti-reflux procedure to the initial myotomy.

The occasional patient with achalasia who fails to respond to myotomy or who presents very late with a significantly dilated and tortuous oesophagus may require an oesophagectomy.

GASTRO-OESOPHAGEAL REFLUX DISEASE

Patients whose symptoms have been confirmed to be secondary to reflux disease generally achieve a good outcome with anti-reflux surgery, thereby avoiding further need for acid-suppressing medication. Although anti-reflux surgery is undertaken mainly for relief of the symptoms, it also prevents the long-term complications associated with reflux disease such as haemorrhage and strictures, which can occur secondary to oesophagitis. Surgery may potentially reduce the progression of Barrett's oesophagus.

PATIENT SELECTION

The ideal candidate for an anti-reflux procedure is a patient with reflux disease who has obtained symptomatic relief from proton-pump inhibitors or H_2-receptor antagonists, is not overweight, has no psychological disorders and who wishes to avoid life-long medication. The operation is generally associated with a successful outcome, gives long-term symptomatic control and, as it can be carried out laparoscopically, provides an attractive alternative to medical management. However, with the dramatic increase in referrals for anti-reflux surgery, it is important that indications for intervention are well defined and that the operation is carried out by surgeons in institutions experienced in the procedure and who have the ability to deal with any operative complications.

Before embarking on operative intervention, patients should undergo a number of clinical and radiological tests to confirm the diagnosis of reflux disease and to identify any independent motility disorder. These tests allow the surgeon to decide on the appropriate intervention and they also provide information on anatomical anomalies, such as oesophageal diverticulae, shortened oesophagus and para-oesophageal hernia, which will be deleterious to the outcome if not discovered preoperatively and surgery planned appropriately. Investigations are particularly pertinent for patients with atypical symptoms and for those who continue to have significant symptoms despite the use of proton-pump inhibitors.

Typical investigations include:

- *Upper endoscopy*. This is critical as it identifies oesophagitis and other reflux complications such as stricture. Biopsies are taken if there is Barrett's oesophagus with suspected metaplasia on malignancy. It is important during endoscopy to note the presence of a hiatal hernia, as this may influence the choice of surgical approach.
- *24-hour pH monitoring* identifies oesophageal exposure to acid and its correlation with symptoms. It differentiates between supine and upright reflux disease. It is an objective test and a good indicator of the potential response to surgery. Twenty-four-hour pH monitoring is particularly useful for confirming the presence of reflux disease in patients in whom upper endoscopy was negative for oesophagitis. Disadvantages of the test include the need to discontinue proton-pump inhibitors prior to the test and discomfort from insertion of the pH probe.
- *Manometry* will measure the lower oesophageal sphincter pressure, which in patients with reflux disease is usually reduced consistent with an incompetent lower oesophageal sphincter. It will help identify motility disorders such as achalasia and may be useful in deciding the type of anti-reflux surgery that would best combat the individual patient's symptoms.
- *Barium swallow* is an important adjunct in the investigation of reflux disease. It provides specific anatomical information on the presence of hiatal hernia, oesophageal stricture and shortened oesophagus. A barium swallow will also help in the identification of motility disorders and delayed gastric emptying.

OPEN VERSUS MINIMAL-ACCESS SURGERY

Laparoscopic anti-reflux surgery is now the 'gold standard' for the surgical management of patients with gastro-oesophageal reflux disease. There is no difference in functional results between the open and laparoscopic approach, but the benefits of a minimal-access approach include reduced postoperative pain, avoidance of a laparotomy or thoracotomy scar, early mobilisation and a shorter hospital stay. Patients undergoing a minimal-access fundoplication may underestimate the operation and should be aware of the risk of splenic injury, oesophageal perforation, pulmonary complications and the occasional necessity to convert to an open procedure. Relative contraindications to the performance of laparoscopic anti-reflux surgery include a previous vagotomy or gastrectomy.

ABDOMINAL VERSUS THORACIC APPROACH

This debate has continued from the 'open' era. Most indications for one or other approach, whether by an open or a minimal-access technique, are relative rather than absolute, and much depends on the surgeon's preference and experience. Some surgeons favour a transthoracic approach to anti-reflux surgery when reflux disease is complicated by a fixed hiatal hernia or the patient has had a previous failed repair performed from below. It may also be a better approach in the morbidly obese.

PARTIAL OR COMPLETE WRAP

Partial wraps have a lower incidence of dysphagia and gas bloat than the Nissen total wrap. However, partial wraps may be less effective in eliminating reflux. Most surgeons favour a total wrap except in specific circumstances. For example, a Dor partial wrap may be considered as an anti-reflux procedure in combination with a Heller's cardiomyotomy and, if it is sutured laterally to the edges of the myotomy, the wrap helps to keep the muscle fibres apart (see Chapter 17, p. 267). Occasionally, only a partial wrap is possible, as when the available fundus is limited by previous gastric surgery. Also, a complete wrap that is causing excessive dysphagia can be taken down and converted to a partial fundoplication. A recent meta-analysis of randomised controlled trials has demonstrated that an anterior 180-degree partial fundoplication achieves durable control of reflux symptoms and fewer side-effects compared with the Nissen total wrap.[3]

Some surgeons believe that elderly patients, patients with reduced oesophageal contraction amplitudes and those with a specific coexisting oesophageal dysmotility disorder may fare better with a partial wrap, such as provided by the Toupet technique. This has not, however, been universally supported by trials and selection is mainly based on personal experience.

Surgery for Barrett's oesophagus

In gastrointestinal reflux disease the distal oesophagus may become lined with columnar epithelium as a consequence of the exposure to gastric juices. Intestinal metaplasia within this area is associated with an increased risk of adenocarcinoma of the oesophagus. As a consequence, such patients are placed under regular endoscopic surveillance programmes with multiple biopsies performed to identify early dysplastic or neoplastic change. This is combined with intensive management to reduce the damage from reflux. Regression of these premalignant changes, by profound pharmacological acid suppression with proton-pump inhibitors, can be demonstrated but there is no clear evidence that the addition of anti-reflux surgery improves regression. Endoscopic radiofrequency ablation of metaplastic and dysplastic areas has been shown to be a safe and effective treatment and it reduces the risk of disease progression.[4] Unfortunately, high-grade dysplasia may still develop, and in a proportion of patients this finding predicts that early invasive cancer has already developed, although not within the biopsy specimen. In one series some 50 per cent of patients with Barrett's oesophagus who underwent oesophagectomy for an area of high-grade dysplasia had pathological evidence of invasive cancer in the resected specimen. The risk of postponing intervention until there is unequivocal but possibly incurable cancer led many gastroenterologists and surgeons to believe that the finding of high-grade dysplasia was an indication to abandon surveillance and recommend oesophagectomy in fit patients. However, recent cohort studies have shown that the annual risk of adenocarcinoma in patients with Barrett's oesophagus is 0.12 per cent, and 0.26 per cent in those with high-grade dysplasia.[5] This incidence is lower than previously thought and may lead to a re-evaluation of the screening programmes.

HIATAL AND DIAPHRAGMATIC HERNIAE

Hiatal hernia

Hiatal herniae occur when the stomach or other intra-abdominal organ herniates through the diaphragmatic oesophageal opening into the chest. They can be divided into sliding and rolling (para-oesophageal) herniae.

SLIDING HIATAL HERNIA (TYPE 1)

This is the commonest type, accounting for over 90 per cent of cases (Figure 18.1a). The cardia and the oesophagogastric junction undergo cephalad migration through the diaphragm into the posterior mediastinum, but maintain their anatomical relationship. In the initial stages the oesophageal length is normal and there is no true peritoneal sac. Patients commonly complain of reflux symptoms, which are attributed to functional disruption of the lower oesophageal sphincter. These herniae do not need to be considered for

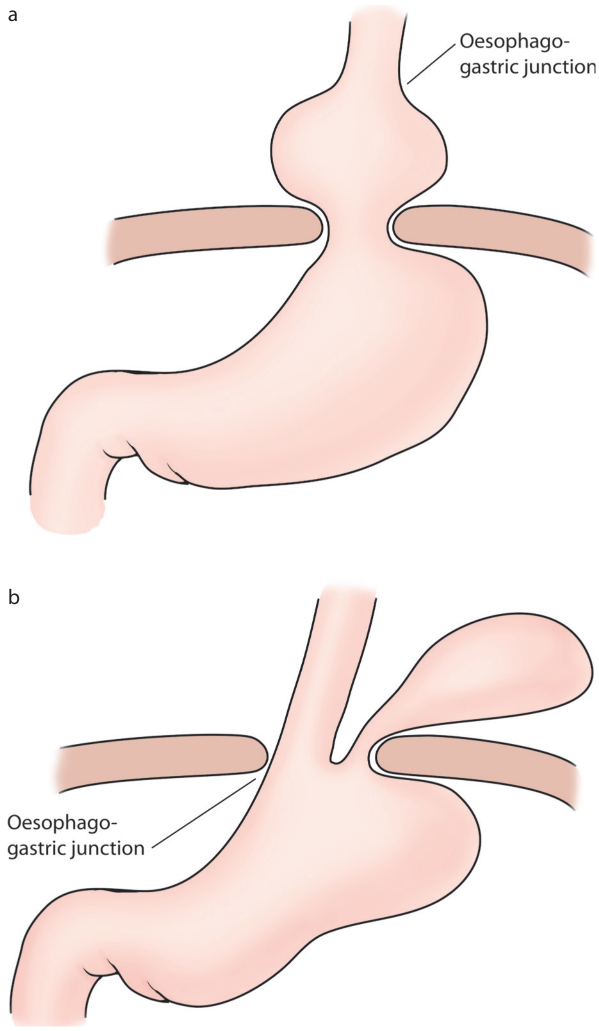

Figure 18.1 *(a) Sliding hiatus hernia. (b) Rolling hiatus hernia.*

repair unless they are associated with pathological reflux that significantly interferes with the patient's quality of life.

When surgery is indicated, reduction of the hernia is combined with closure of the crural defect and an anti-reflux procedure. This is usually performed laparoscopically. If the hiatal defect is very large, a synthetic mesh may be inserted, giving a tension-free repair (Figure 18.2). Prior to insertion a hole is cut in the mesh to accommodate the oesophagus. The mesh is then stapled to the diaphragm, taking care to avoid damaging the oesophagus and piercing the pericardium. Radiological recurrence has been disappointingly high after laparoscopic repair of these very large hiatal defects and is discussed further below.

PARA-OESOPHAGEAL (ROLLING) HIATUS HERNIA

Para-oesophageal (rolling) hiatus herniae are subdivided into three types:

- *Simple rolling hiatus hernia (type II)*. Here, the oesophagogastric junction remains below the diaphragm, despite the gastric fundus rolling along the oesophagus (Figure 18.1b). The oesophagogastric junction remains tethered to the diaphragm by an intact phreno-oesophageal ligament and oesophageal length is maintained. This type of para-oesophageal hernia is found predominantly in the elderly. Iatrogenic para-oesophageal herniation is seen with increased frequency as a complication following anti-reflux surgery.
- *Mixed para-oesophageal hernia (type III)*. This consists of a combination of type I and type II, in which both the fundus and the cardia migrate above the diaphragm.
- *Large para-oesophageal hernia (type IV)*. In this case the spleen, colon, small bowel, stomach or other intra-abdominal organ herniates into the mediastinum through the hiatal defect. This type carries a significant risk of strangulation.

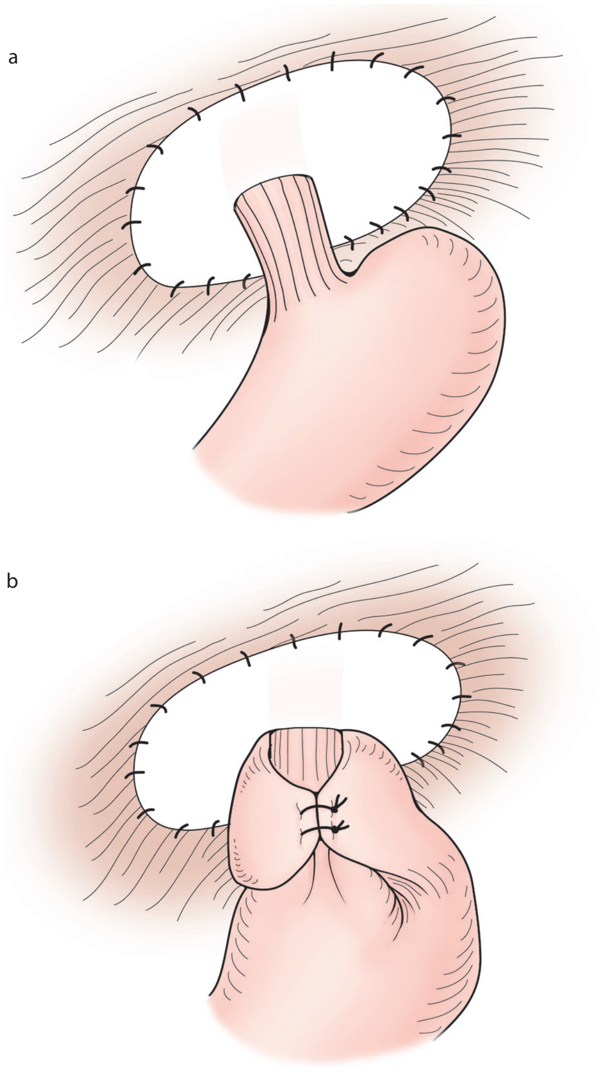

Figure 18.2 *Repair of a large para-oesophageal hernia. (a) A mesh can be used to close a large defect. (b) After the hiatal patch is in place, the repair is completed with a wrap to prevent oesophagogastric reflux.*

Most para-oesophageal herniae are asymptomatic and the diagnosis is often a result of an upright chest X-ray that demonstrates an air–fluid level. However, para-oesophageal herniae may present with gastrointestinal symptoms including dysphagia, regurgitation or chest pain. Bleeding from ulcerated gastric mucosa may result in a haematemesis or an iron-deficiency anaemia. Fatalities, secondary to gastric strangulation and perforation, have been well described. Most surgeons would advocate repair in healthy patients, given the inherent risk of strangulation and gastric volvulus. Prior to the advent of minimally-invasive techniques there was reluctance to advise surgery, especially in asymptomatic elderly patients. However, the long-term benefits of repair would now appear to outweigh the operative risks in most patients.

Preoperative investigations should include endoscopy to identify any underlying sinister pathology. It is also important to discover prior to intervention if there is a shortened oesophagus or motility disorder that will influence the type of repair. For example, patients with a shortened oesophagus may require the addition of a Collis gastroplasty to provide an adequate segment of intra-abdominal oesophagus (see Chapter 17, p. 268). CT scans and barium studies are particularly valuable in type IV herniae to determine the type of hernia and to show which abdominal organs have migrated into the hernial sac.

Traditionally, surgeons reduced the herniated contents and then performed a primary closure of the crural defect. However, a significant number of patients went on to develop reflux symptoms that greatly interfered with their quality of life. This may be related to the excessive dissection required to reduce the herniated contents, with disturbance of the functional effect of the lower oesophageal sphincter. Thus, an anti-reflux procedure has since been added to the repair of most para-oesophageal herniae. The hiatal defect may be very large and the crural fibres thinned, such that adequate closure of the defect will require a mesh to provide a tension-free repair.

Laparoscopic repair is now the preferred option in many centres. If the patient presents as an emergency, a minimal-access approach can sometimes still be considered, depending on surgical experience and facilities, but there must be a low threshold for converting to an open technique.

LAPAROSCOPIC REPAIR OF A PARA-OESOPHAGEAL HERNIA

The position of the patient and the placement of the ports are similar to those described for a laparoscopic Heller's cardiomyotomy (see Chapter 17). The stomach, and any other herniated contents of the sac, are gently reduced using Babcock forceps inserted through the left lateral ports. Long-standing adhesions may have to be divided before this can be achieved. The gastrohepatic ligament is then divided, allowing visualisation of the right crural fibres.

The hernial sac is dissected with care off the right crus and the mediastinal structures. This carries the risk of pleural damage with the formation of a tension pneumothorax. If this occurs, then the anaesthetist will experience difficulties ventilating the patient, who may become hypotensive. The pneumoperitoneum is released immediately, which should provide instant resolution. If not, then needle decompression of the affected pleural space followed by chest drain insertion will be required.

Finally, the sac is dissected off the left crus and this is often difficult. Once the sac is freed and returned intra-abdominally, it is excised. The next step is closure of the widened hiatus. The edges of the hiatal defect and posterior oesophageal window are identified. The right and left crural fibres must be adequately visualised. This is greatly helped by elevation of the oesophagus anteriorly and, if necessary, using a soft encircling drain for retraction. The posterior vagus nerve is elevated with the oesophagus. The crura are approximated behind the oesophagus using 2/0 non-absorbable sutures (see Figure 17.7b, p. 270). Starting inferiorly, generous bites are taken and care must be exercised to avoid the underlying aorta. Very rarely, some sutures have to be inserted anterior to the oesophagus. Many surgeons favour the use of endo-suturing devices for crural approximation.

For very large defects (>10 cm in diameter), the cruroplasty is often inadequate and a mesh may have to be inserted (Figure 18.2a). Once the mesh has been cut to size, a 3-cm circular defect with a radial slit is created to accommodate the oesophagus. The mesh is attached to the undersurface of the diaphragm using a stapling device, and care must be taken not to perforate the pericardium. As with any mesh insertion, the patient should receive prophylactic antibiotic cover. A Nissen fundoplication is then created (Figure 18.2b). This is described in more detail in Chapter 17. When completed, the subdiaphragmatic surfaces are irrigated using 10 ml of 0.5 per cent bupivacaine in 500 ml of 0.9 per cent normal saline. This reduces the incidence of postoperative shoulder tip pain. The pneumoperitoneum is then released and the port sites closed. If there is any question of damage to the pleura, the patient should have a chest X-ray on the operating table to rule out a pneumothorax.

Patients are normally allowed oral fluids that evening and a light diet on the next day. It is a procedure that is generally well tolerated, even in elderly patients with a degree of co-morbidity.

Initially, the long-term results of laparoscopic repair of large para-oesophageal herniae were inferior to those following open surgery. In the open approach, it is easier to take a large 'bite' of the diaphragm and, if necessary, make a relaxing incision in the lateral diaphragm to facilitate closure of the crura. Newer laparoscopic techniques, such as crural mesh reinforcement, increasingly with absorbable biological material, have reduced the recurrence rate after laparoscopic repair and some studies show results comparable with open repair.[6]

Congenital adult diaphragmatic hernia

The diaphragm is a musculotendinous structure that separates the thoracic cavity from the abdominal cavity. The pleuroperitoneal membranes close the communication between the pleural and peritoneal cavities at approximately the eighth embryonic week. Incomplete closure of the pleuroperitoneal canal, a phenomenon more common on the left side, gives rise to a posterolateral defect first described by Bochdalek in 1848. Usually, there is no hernial sac and the defect may be as small as 1 cm, but it may involve the entire hemidiaphragm (agenesis). Babies born with large defects usually present neonatally, and their management is discussed in Chapter 13. In contrast, a hernia of Morgagni is more common on the right side. It possesses a hernial sac and occurs through a parasternal defect at the site where the superior epigastric artery leaves the chest and enters the abdomen.

Presentation of Bochdalek and Morgagni herniae in adulthood is quite rare. Most are asymptomatic and only diagnosed when a routine chest X-ray demonstrates bowel within the chest. Some patients have non-specific symptoms, while others present as an emergency with obstruction or strangulation of the intrathoracic bowel or stomach. A CT scan is the investigation of choice to confirm the diagnosis and it provides anatomical information on both the herniated organs and the site of the defect. Barium studies are also useful. Most surgeons would advocate repair, even in asymptomatic individuals, because of the danger of strangulation.

Repair can be undertaken via a laparotomy or thoracotomy or via a laparoscopy or thoracoscopy. The choice of approach will depend on the position and size of the defect and the experience of the surgeon. Dense adhesions are common and have to be divided prior to the reduction of the herniated tissue, which may include bowel, liver and spleen, all of which are easily damaged during dissection. Damage may also occur to the lung or mediastinum. A small diaphragmatic defect can be closed with sutures but a mesh may be required to bridge a larger defect. It is advisable to insert a chest drain into the pleural cavity above the diaphragmatic defect until the lung has fully re-expanded.

Traumatic diaphragmatic hernia

The surgical management of this condition is discussed in the trauma section of Chapter 8.

GASTRIC VOLVULUS

Gastric volvulus is an abnormal rotation of the stomach that can cause a closed loop obstruction. It is usually associated with underlying pathology such as a para-oesophageal or diaphragmatic hernia. Patients may present with chronic non-specific symptoms including vomiting and postprandial epigastric pain. Once diagnosed, most surgeons would recommend repair, given the potential for catastrophe. A proportion of patients will present with severe pain and retching, without the ability to vomit. The inability to pass a nasogastric tube beyond the distal oesophagus completes *Borchardt's triad*. This is a closed loop obstruction, which causes progressive gastric distension and represents a surgical emergency as the blood supply to the stomach may be rapidly compromised. There are two types of gastric volvulus defined by their axis of rotation: organo-axial and mesentero-axial.

An *organo-axial* volvulus occurs around a line between the pylorus and the oesophagogastric junction and is more common in elderly people (Figure 18.3a). Occasionally, there is a gastric tumour at the apex of the rotation.

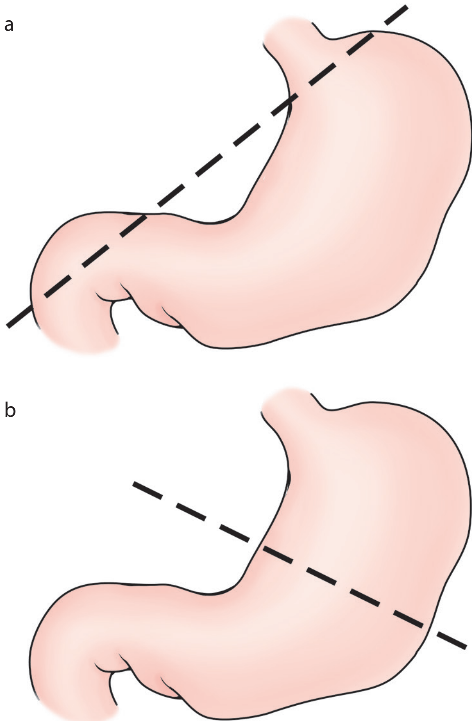

Figure 18.3 *Gastric volvulus. (a) Organo-axial rotation on an axis between the pylorus and the oesophagogastric junction. (b) Mesentero-axial rotation occurring on an axis from the porta hepatis to the greater curvature of the stomach.*

A *mesentero-axial* rotation occurs in a plane running from the porta hepatis to the greater curve of the stomach, and has a higher incidence in children (Figure 18.3b). Very rarely, a combined form is encountered.

When a patient presents acutely with suspected gastric volvulus, an attempt should be made to pass a nasogastric tube. This may decompress the stomach and allow a subsequent elective procedure. If nasogastric deflation fails, endoscopic decompression may be successful but carries a risk of gastric perforation. If decompression is not achieved, emergency surgery is essential to reduce the volvulus. If the stomach is viable and there is no evidence of coexisting pathology, a simple gastropexy in which the anterior stomach wall is sutured to the anterior abdominal wall should suffice. If there are adhesive bands, these are divided and any associated diaphragmatic defect is repaired. In the presence of gastric necrosis or perforation, a subtotal or total gastrectomy may be unavoidable.

There are several other methods of fixing the stomach to prevent recurrent volvulus. It can be fixed to the anterior abdominal wall by a gastrostomy or its mobility restricted by a gastrojejunostomy. A percutaneous endoscopic gastrostomy (PEG) tube is another method of fixation and may be the most suitable for high-risk patients.

PEPTIC ULCER DISEASE AND ASSOCIATED COMPLICATIONS

Historical perspective

Elective operations for peptic ulcer were among the commonest procedures performed by the general surgeon in the middle decades of the last century. The original operations of Billroth I gastrectomy and gastroenterostomy alone were replaced by the Polya gastrectomy and, later, to a greater extent by vagotomy and drainage procedures. Gastroenterostomy and the Polya gastrectomy diverted gastric acid from the ulcer, but in general the main surgical objective was to reduce acid secretion. A partial gastrectomy reduced acid both by the removal of a portion of the parietal cell mass and by the excision of the gastrin-producing antrum, thus reducing stimulation of the remaining parietal cells. Vagotomy abolished vagal stimulation of the parietal cell mass. A vagotomy with antrectomy was probably the most effective operation, but it was associated with the side-effects of both a truncal vagotomy and a partial, albeit limited, gastrectomy. Debate regarding the best operation for peptic ulceration focused on the balance between the incidence of recurrent ulceration and the incidence and severity of side-effects.

The whole situation changed with pharmacological advances. As the operations were designed to reduce acid secretion of the stomach, their role became increasingly unimportant as more potent antisecretory drugs became available. The identification of *Helicobacter pylori* as a causative agent, combined with effective regimes for its eradication, further changed surgical practice. The majority of patients could be cured and did not require long-term acid suppression. The elective management of peptic ulcer disease is now almost exclusively medical. H_2 receptor antagonists or proton-pump inhibitors are used to block acid secretion, and *Helicobacter* is eradicated with antibiotics.

Surgery is now mainly confined to management of the complications of peptic ulcer disease, including perforation, haemorrhage and gastric outlet obstruction. Despite decreasing incidence, peptic ulcer perforation and haemorrhage are still major causes of morbidity and mortality. Surgery is also occasionally indicated for ulceration refractory to medical treatment and for the complications of previous peptic ulcer surgery. The latter are discussed in the section on late complications of upper gastrointestinal surgery at the end of this chapter.

Refractory ulcers

With modern drugs, patients with refractory ulcers form a very small subgroup of those with peptic ulceration. This subgroup have ulcers that are also less likely to be cured by many of the standard operations that were effective in the past for the majority of an unselected group of patients. This was first recognised in the 1980s, but with advances in pharmacology this must be an even more important consideration today.[7] Also, increasingly, an underlying pathology must be sought for a refractory ulcer and malignancy must always be considered, especially in gastric ulcers. A refractory gastric ulcer usually warrants a gastrectomy, which will also excise the ulcer. It is likely that if surgery has to be considered in patients with resistant duodenal ulcers, resection of the gastrin-producing mucosa of the antrum should be combined with either denervation of the parietal cell mass or the excision of a major part of it. A subtotal gastrectomy is one possibility, but it is associated with significant long-term morbidity. A truncal or selective vagotomy, combined with antrectomy, is probably the preferred option. Reconstruction can be either with a gastroduodenal (Billroth I) anastomosis or with a gastrojejunostomy, either as a Billroth II (Polya) anastomosis or as a Roux loop. In a recent analysis of the long-term outcome of patients who underwent a partial gastrectomy with vagotomy for duodenal ulceration in the 1980s, superior outomes were shown in patients who underwent a Roux-en-Y anastomosis compared with a Billroth II anastomosis.[8]

Zollinger–Ellison syndrome, in which a gastrin-secreting tumour is stimulating gastric hypersecretion, should be remembered. When these are solitary tumours within the pancreas and have not metastasised, resection can be curative. In many patients this is not the case, and management is by controlling acid hypersecretion. Before effective acid-suppressing drugs were available, a total gastrectomy was often necessary. However, with the emergence of H_2 receptor antagonists, a combination of these drugs with a parietal cell vagotomy was preferred. Nowadays, proton-pump inhibitors may be sufficient to control hypersecretion, without the necessity for surgery at all.

Gastric outlet obstruction

Chronic peptic ulcer disease can give rise to gastric outlet obstruction. The persistent inflammation causes intense fibrosis and scarring with subsequent channel narrowing. This presentation of chronic peptic ulcer disease is now less common in the Western world. In contrast, in the acute setting the obstruction may be secondary to oedema and inflammation associated with the ulcer, in which case symptoms tend to settle within a few days of conservative management.

The initial management of gastric outlet obstruction consists of insertion of a wide-bore nasogastric tube and correction of fluid and electrolyte imbalance. Intravenous proton-pump inhibitor therapy is commenced. The diagnosis is established by barium meal, CT or upper gastrointestinal endoscopy. Imaging may identify a dilated, atonic stomach with an absent or narrowed pyloric channel, and it may take several hours for the stomach to empty of contrast. Occasionally, an hourglass deformity of the stomach, secondary to a fibrous stricture from gastric ulcer disease, is demonstrated. On endoscopy the stomach may be dilated and visualisation limited by undigested food. However, endoscopy has the advantage of enabling the mucosa at the site of the stricture to be inspected and biopsies to be taken if there is a suspected malignancy. Malignant gastric outlet obstruction is considered later.

Even in acute peptic ulcer disease, if gastric outlet obstruction fails to respond to conservative management, definitive surgery may be necessary. Surgical options depend on intraoperative findings. The pylorus is usually too oedematous or scarred for a pyloroplasty to be an option. A gastroenterostomy is the simplest drainage option but, when carried out for active peptic ulcer disease, a vagotomy should also be undertaken. Avoidance of a full truncal vagotomy may reduce the incidence of post-vagotomy diarrhoea. If a resection is chosen, an antrectomy with vagotomy may be possible if the duodenal bulb is not too severely deformed. If the duodenum is considered unsafe for an anastomosis, a Billroth II reconstruction or a Roux-en-Y loop may be indicated (see Chapter 17).

The decision is slightly different in the unfit elderly patient with a fibrous stricture from previous ulceration but no active ulcer disease. It was for this latter group, who are decreasingly encountered in Western practice, that Eric Farquharson defended the old operation of gastroenterostomy alone.

Penetrating and giant ulcers

Giant peptic ulcers of the stomach or duodenum that penetrate the pancreas or liver or fistulate into the transverse colon or other adjacent viscera are now fortunately rare in the UK. They may, however, be encountered more frequently in other parts of the world. The surgery for these ulcers must usually involve a gastrectomy with a Billroth II or Roux loop reconstruction. As there will be no residual mucosa in the base of a gastric ulcer that has penetrated the liver or pancreas, it is simply circumcised and left *in situ* as the stomach is mobilised for the gastrectomy. A giant posterior penetrating duodenal ulcer usually precludes closure of the duodenal stump, and overenthusiastic attempts may result in injury to the common bile duct. If closure involves any excess tension on the stump or the tissue is unable to hold sutures adequately, then it may be better to create a controlled duodenal fistula. This is done by inserting a Foley catheter into the stump and anchoring it with a purse-string suture (Figure 18.4a). The area is then buttressed using greater omentum. Alternatively, a lateral duodenostomy tube can be inserted (Figure 18.4b) or even a large-bore tube simply secured in the vicinity of the open duodenal stump. Once the catheter or T-tube has been removed, the duodenal fistula should close spontaneously if there is no afferent limb obstruction.

When there is a fistula into the transverse colon, the colonic wall defect is often small and may be amenable to primary closure. Occasionally, a more extensive resection or a defunctioning stoma may be required (see Chapters 22 and 23).

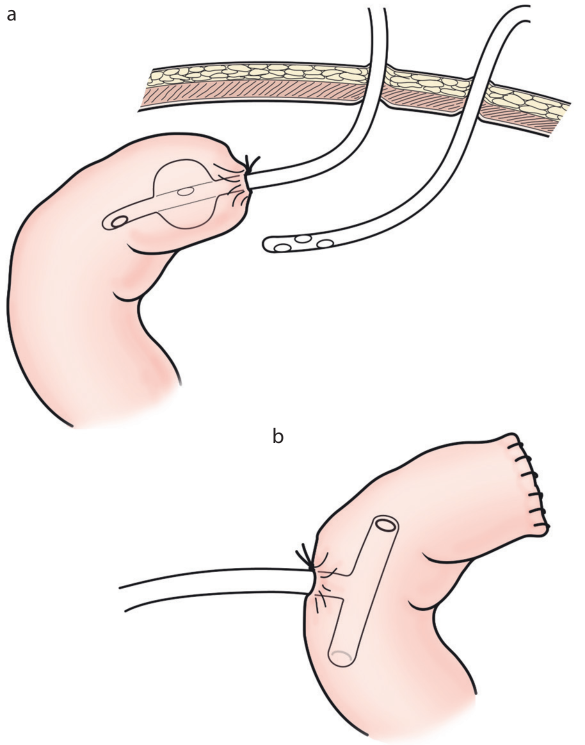

Figure 18.4 *Solutions for the difficult duodenal stump. A controlled fistula onto the skin surface can be created with: (a) a Foley catheter inserted into the duodenum or even with a drain left adjacent to an open duodenal stump; (b) a lateral duodenostomy using a T-tube.*

Emergency peptic ulcer surgery

Most operations nowadays for peptic ulcer are performed for acute complications. The surgeon must decide at the time of the emergency surgery whether any definitive acid-reducing procedure should be carried out at the same time. The debate regarding the correct policy in an emergency scenario has continued for over half a century. Even before medical treatment was so effective, it was recognised that many patients who presented with a perforation or haemorrhage did not require further medical or surgical treatment for chronic peptic ulcer disease. In these patients acid-reducing surgery was unnecessary; it exposed the patients to the long-term complications of the surgery, and it also prolonged an otherwise simple operation at a time when the patient might be septic or haemodynamically unstable.

However, in other patients a definitive procedure simplified their subsequent management and avoided a later elective operation. With improvements in medical management, such that very few patients come to elective surgery for peptic ulcer disease, the argument for definitive surgery at the time of an emergency intervention has been weakened. However, if the patient has developed a complication while receiving medical treatment, or has had a previous perforation or bleed, a definitive procedure at the time of the emergency operation may still be considered.

Sometimes a surgeon is forced into a more major procedure by the conditions encountered at the emergency operation. For example, a large ulcer in a grossly scarred or stenosed pylorus may be causing an outflow obstruction in addition to a perforation. A gastroenterostomy becomes necessary for gastric drainage and should not be performed in active peptic ulcer disease without a vagotomy, otherwise there is a significant risk of stomal ulceration. Giant duodenal ulcers that have perforated, are actively bleeding, or both, can sometimes only be managed by gastrectomy.

PERFORATED PEPTIC ULCER

The classical presentation of a perforated peptic ulcer involves sudden onset of epigastric pain. An erect chest X-ray will reveal free air in approximately 65 per cent of cases. Often, although a perforated ulcer is suspected, only a preoperative diagnosis of a perforated viscus or generalised peritonitis is possible. After resuscitation and elimination of non-surgical pathology, an emergency laparotomy or laparoscopy is planned as discussed in Chapter 15. Turbid, bile-stained fluid confirms an upper, rather than a lower, gastrointestinal perforation.

Open operation

In most cases the perforation is easily recognised. The anterior aspect of the first part of the duodenum and distal stomach are inspected first. A retractor is carefully inserted under the liver and the stomach is drawn down, grasping it with a moist pack (Figure 18.5a). Overlying omentum is peeled away.

If no perforation becomes apparent, the remainder of the anterior aspect of the stomach and duodenum is inspected. On rare occasions a posterior ulcer has perforated into the lesser sac.

Duodenal perforation. A perforated duodenal ulcer is most appropriately managed by simple closure with three or four interrupted, absorbable sutures. Generous bites, which pass through the entire thickness of the gut wall, should be taken. Care must be taken to ensure that they do not catch the posterior wall. Sutures should be inserted in the long axis of the gut to avoid narrowing (Figure 18.5b). The closure should then usually be reinforced with an omental on-lay patch, a '*modified Graham patch*' (Figure 18.5c). If the ulcer is large and inflamed, the sutures tend to 'cheese-wire' through the tissues and it is better not to attempt to draw the edges together. Instead, the defect is closed using an omental patch alone – a '*true Graham patch*'.

As discussed above, the addition of a definitive acid-reducing procedure is seldom justified, but when indicated a truncal vagotomy and drainage procedure is usually the most appropriate. The choice between pyloroplasty and gastroenterostomy is dictated by the conditions prevailing in the pyloroduodenal area. Where possible, a perforation is incorporated in a pyloroplasty, but significant stenosis may mean that simple closure of the perforation and a gastroenterostomy are preferable.

Occasionally, the entire duodenal wall is eroded and it may be necessary to proceed to a Billroth II gastrectomy. In these circumstances, closure of the duodenal stump is unlikely to be possible but a controlled duodenal fistula can be created by tube drainage (see Figure 18.4).

Gastric perforation. Perforated gastric ulcers may be malignant and should therefore be excised or sufficient biopsies taken prior to primary closure of the perforation. The closure is again reinforced using an omental patch. Occasionally, if the ulcer is very large, a gastrectomy may be required. A perforated, overtly malignant gastric ulcer can pose difficult intraoperative decisions, especially if a gastrectomy cannot be performed through tumour-free planes. Any surgery, even for a small malignant ulcer that has perforated, is almost certainly palliative because of the contamination of the peritoneal cavity with malignant cells.

It is important to ensure thorough peritoneal toilet after the closure of any gastrointestinal perforation in order to reduce wound infections and intra-abdominal abscess formation. However, in recent years the concept of copious irrigation has been challenged. The concern is the noxious effect of irrigation fluid on neutrophils and peritoneal mesothelial cells, which play a central role in the immune response to peritoneal infection. Postoperatively, as soon as it is possible, patients should be commenced on triple therapy for *Helicobacter pylori* eradication. If the patient fails to settle postoperatively, the possibility of an intra-abdominal abscess must be considered. In most cases, when identified on ultrasound or CT scan, an abscess may be drained percutaneously under radiological guidance. The possibility that the patient has a persistent duodenal leak should be considered. This can be confirmed or excluded with water-soluble contrast studies.

Laparoscopic repair of a perforated peptic ulcer

This is becoming the more popular option. However, whereas an open repair is usually a simple procedure, a laparoscopic repair requires the surgeon to be proficient with intracorporeal knot tying. The fibrin seal between the undersurface of the liver, gallbladder and the perforated ulcer is gently divided to expose the ulcer, with care being taken not to enlarge the existing perforation. The principles are then similar to those for an open technique. The laparoscopic approach allows better access and vision for peritoneal lavage, particularly in the subphrenic and pelvic spaces.

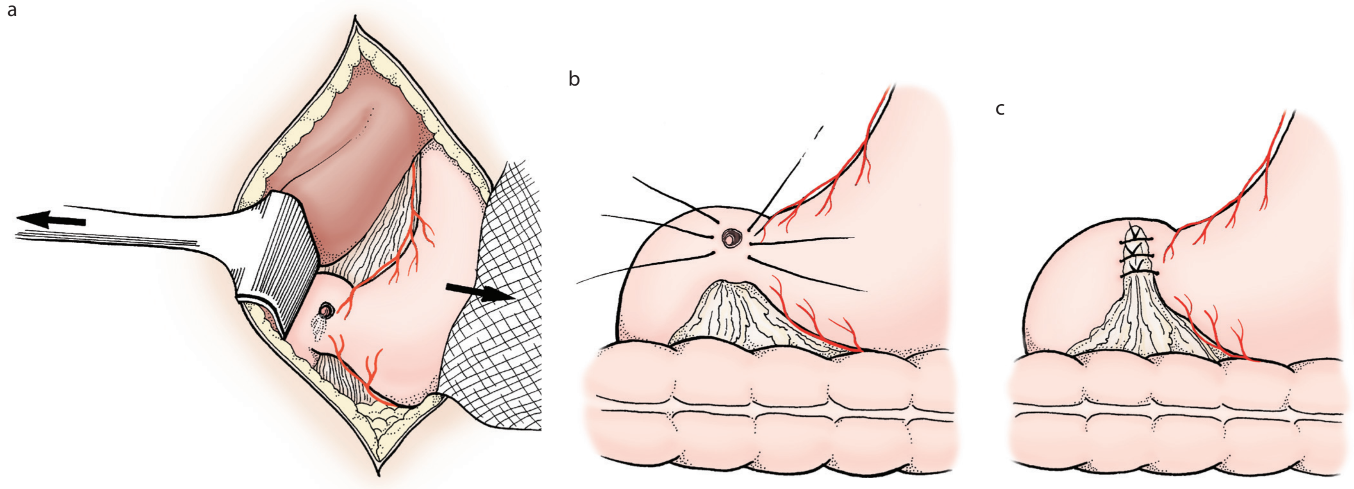

Figure 18.5 *Perforated duodenal ulcer. (a) Good retraction facilitates access to the duodenum and the identification of the perforation site. (b) Sutures in place for a primary closure of the perforation. (c) This can be reinforced with an omental patch using the same sutures.*

Conservative management of a perforated peptic ulcer

This is more appropriate for duodenal than for gastric perforations and may be considered for patients with a delayed presentation (i.e. greater than 24 hours) and extensive co-morbid factors. In patients who are haemodynamically stable with minimal abdominal symptoms, the ulcer may already be sealed by the greater omentum or adjacent organs. A non-operative approach involving adequate rehydration, nasogastric tube aspiration, broad-spectrum antibiotics, thromboembolic prophylaxis and acid suppression has been shown to be effective in a selected group of patients. Patients are monitored closely, and any deterioration in clinical status will be an indication for operative intervention. The patient is susceptible to the development of subhepatic or subphrenic abscesses but, in the absence of generalised peritonitis, these can be managed by image-guided percutaneous drainage.

PEPTIC ULCER HAEMORRHAGE

Peptic ulcer disease, presenting as haematemesis and melaena, is a common cause of upper gastrointestinal tract bleeding. The three cardinal principles in the management are:

1. Vigorous resuscitation of the initial bleed to restore haemodynamic stability, followed by monitoring for re-bleeding and appropriate resuscitation if this should occur.
2. Prompt investigation to establish the cause.
3. Institution of appropriate measures to arrest bleeding and prevent further haemorrhage.

Gastroscopy has long been the diagnostic procedure of choice, but now it has become the principle therapeutic option. Depending on expertise and available resources, endoscopic treatment options include injection of the bleeding ulcer with adrenaline or sclerosant, laser photocoagulation and coagulation with bipolar diathermy. It is now uncommon for surgery to be necessary, but it must always be considered when bleeding persists or recurs despite endoscopic intervention. Although repeat endoscopic intervention may be successful, mortality from salvage surgery, if it becomes necessary, increases with delay. The old lessons on the dangers of procrastination must not be forgotten. A large vessel, visible in the ulcer base, a major initial bleed, a re-bleed in hospital and advanced age are all factors that should encourage surgical intervention. If facilities exist, radiological embolisation is an alternative strategy for patients in whom endoscopic treatment has failed.

Operative procedure

Upper gastrointestinal endoscopy, except in hospitals where it is unavailable, is imperative prior to operative intervention to identify the site of haemorrhage, as this will direct surgical access towards the bleeding site. Very occasionally, the bleeding is so torrential that the patient must be taken directly to the operating theatre. In this situation, endoscopy can be performed in theatre after induction, but this may be unhelpful if major haemorrhage is obscuring the view. A midline laparotomy, with division of the falciform ligament to allow upward retraction of the liver, should give good access.

Duodenal ulcer. If the bleeding is from a duodenal ulcer, two stay sutures are inserted either side of the pylorus using the prepyloric vein of Mayo as a guide. A longitudinal pyloroduodenotomy is made and direct finger pressure on the bleeding site will control the haemorrhage, allowing the anaesthetist to resuscitate and stabilise the patient. If the bleeding site is not obvious, then careful inspection and palpation may identify an area of induration, which represents a thrombosed vessel. Careful lavage and gentle suction will help to dislodge clots that overlie the bleeding vessel. With a bleeding gastroduodenal artery, sutures should be inserted to gain control. Sutures are placed proximally and distally on the gastroduodenal artery, and a third suture is inserted to control its transverse pancreatic branch, which may be a cause of re-bleeding if not ligated (Figure 18.6). (This risk of futher bleeding has led some surgeons to recommend a gastrectomy as the alternative surgical option.) Placement of sutures too deeply should be avoided due to the risk of incorporating the pancreatic or common bile duct. Interrupted sutures are then used to close the pyloroduodenotomy incision transversely, to prevent narrowing of the pyloric channel. As discussed above, there is seldom any justification for adding a definitive anti-secretory procedure.

Postoperatively, patients must be monitored closely because of the risk of re-bleeding, which tends to occur within the first 72 hours and carries a significant mortality.

Gastric ulcer. Ideally, the precise site of the bleeding has been identified by preoperative gastroscopy, and an ulcer can be located by palpation of the relevant area of the stomach.

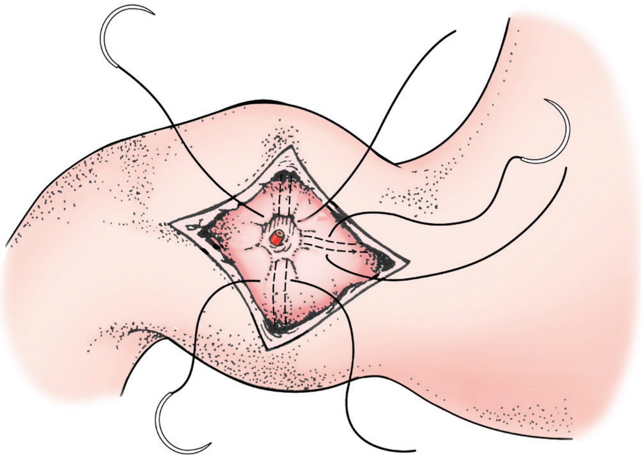

Figure 18.6 *Suture ligation of a bleeding gastroduodenal artery. The sutures must incorporate the artery proximal and distal to the site of the bleeding ulcer, and must also control its transverse pancreatic branch.*

When a posterior ulcer is suspected, the lesser sac will have to be entered to examine the posterior aspect of the stomach. An antral or pyloric ulcer may be detected by digital palpation of the mucosa through a pyloroduodenotomy, if this has already been performed. If no bleeding site can be identified, it may be necessary to make a second gastrotomy. Intraoperative endoscopy can also be helpful in identifying the bleeding point and directing the placement of gastric incisions.

Once the bleeding point has been identified, the surgeon must decide on the most appropriate strategy. Undersewing of the bleeding vessel from within should secure haemostasis, and this is often recommended for the small Dieulafoy lesion. In contrast, a very large ulcer eroding into a major branch of the left gastric artery may necessitate a subtotal gastrectomy incorporating the ulcer. Some surgeons prefer a gastrectomy in all cases, because of the risk of re-bleeding and the concern that an ulcer might be malignant. The pylorus is divided between non-crushing clamps. The distal stomach is then elevated in a cephalad direction, which exposes the left gastric artery and facilitates application of a vascular clamp. This should control bleeding from ulcers involving the lesser curve and this can be confirmed by releasing the distal stomach clamp. Thereafter, the branches of the left gastric artery along the lesser curve may be divided in a controlled fashion from the pylorus to a point proximal to the ulcer. The vascular clamp on the left gastric artery is then released. If haemostasis is achieved, the stomach may then be divided using staplers. If feasible, a Billroth I-type anastomosis can be performed, but if there is any risk of undue tension on the suture lines, then a Billroth II anastomosis is safer.

An ulcer high on the lesser curve, which is eroding the left gastric artery, may not be included in a standard partial gastrectomy. It can be incorporated into the resection by a Pauchet manoeuvre, in which the ulcer is excised with a tongue of gastric wall. A new ‘lesser curve’ is created by apposing the cut anterior and posterior gastric walls with a continuous absorbable suture (Figure 18.7).

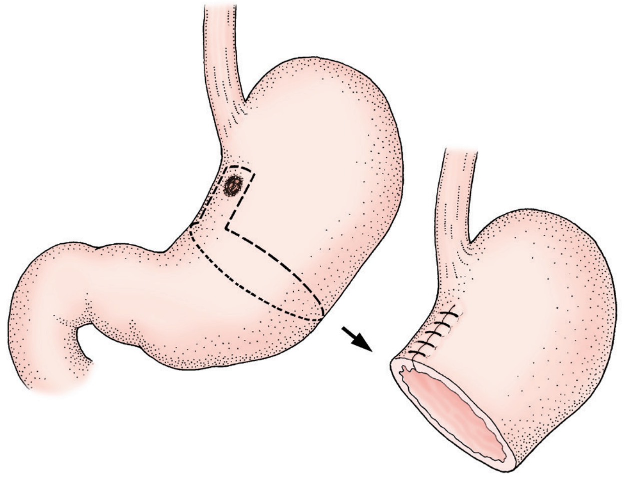

Figure 18.7 *Pauchet manoeuvre.*

SURGICAL MANAGEMENT OF BLEEDING OESOPHAGEAL VARICES

Bleeding oesophageal varices, secondary to portal hypertension, can be a challenging emergency. The bleeding may be torrential and many patients have severely compromised liver function. Non-operative management has the best outcome. The only surgically effective way to arrest massive bleeding is an oesophageal transection with end-to-end anastomosis using a circular stapling device. The stapler is introduced through a gastrotomy and a purse-string suture draws the oesophagogastric junction into the stapler (see Figure 14.16, p. 239).

Endoscopic treatment

Endoscopy is essential to rule out other causes of bleeding, as many patients with known oesophageal varices are bleeding from a duodenal ulcer or gastritis. Treatment options at endoscopy include sclerosant injection, clip placement or banding of the varices. In patients in whom endoscopic treatment either is not possible or is unsuccessful, and bleeding continues, a Sengstaken Blakemore tube can be inserted. Such patients are usually intubated and ventilated, and this will provide airway protection as the tube is inserted. The tube must be well lubricated and it can then be inserted either nasally or orally. The volumes to which the gastric and oesophageal balloons are inflated vary, and it is important to read the manufacturer’s instructions and to inflate accordingly. In general, the gastric balloon is inflated with 250 ml of air and brought back onto the oesophagogastric junction. The oesophageal balloon is then inflated to approximately 120 ml of air, but this can be increased to 150 ml if the haemorrhage is not controlled. It should be remembered that in addition to bleeding oesophageal varices, the patient may have bleeding from gastric varices, which will not be controlled by the tube. After insertion, the position of the tube and balloons should be checked by chest X-ray.

Pharmacological management

Pharmacological management of an acute variceal haemorrhage consists of intravenous vasopressin, which constricts mesenteric arterioles reducing portal blood flow. An alternative drug with fewer side-effects is octreotide, which inhibits the release of vasodilatory hormones and thus reduces splanchnic circulation. Oral neomycin and lactulose reduce the incidence of encephalopathy by reducing the nitrogen available for absorption from the gut.

Transjugular intrahepatic portosystemic shunt

A transjugular intrahepatic portosystemic shunt (TIPSS), an angiographically created shunt between the hepatic and portal veins that decompresses the portal system, may be used in patients who fail to respond to pharmacological and endoscopic therapy. A surgical total or selective portocaval shunt is a possibility if TIPSS is unavailable, but this carries a high mortality in the emergency setting (see Chapter 21).

MORBID OBESITY

Morbid obesity is defined as a body mass index (BMI) greater than 40 kg/m^2, although many patients are well in excess of this. Morbid obesity is increasingly recognised as a medical condition, with serious implications for both health and longevity. As non-operative management of obesity frequently fails, surgical intervention has an important role. However, the increased morbidity associated with obesity places these patients in a high-risk group for surgery. A minimal-access approach has been particularly successful in the morbidly obese, and much of the recent expansion in bariatric, or obesity, surgery has been laparoscopic. It is imperative that any underlying medical conditions or psychological disturbances that may be contributing to the patient's weight gain are identified and addressed. Correct patient selection in conjunction with a multidisciplinary approach is the key to achieving a successful sustained weight reduction. The recent success of bariatric surgery has led to greatly increased demand, which in the UK has caused issues with funding. The surgery is rationed and certain criteria must be met, with the result that it cannot be offered to all who might benefit.

Operations for morbid obesity are based either on the concept of reducing the intake of food (restrictive) or inducing malabsorption of the excessive intake (bypass). Many of the more sophisticated operations combine the two concepts. The most commonly performed operations include the sleeve gastrectomy, the adjustable gastric band, the Roux-en-Y gastric bypass and the biliopancreatic bypass switch operations.

An experienced anaesthetist is most important and it is essential that the operating table can take the weight of the patient in both the flat and steep head-up tilt. Many of these obese patients have asymptomatic gallstones and the advisability of a cholecystectomy at the time of the initial surgery should be considered if any operation is to be performed that would prevent easy endoscopic access to the biliary tree.

VERTICAL BANDED GASTROPLASTY

Vertical banded gastroplasty was one of the early open 'restrictive' operations. The principle of restrictive operations stemmed from the clinical observation that patients who had undergone a total or subtotal gastrectomy lost significant amounts of weight. The advantage of this procedure is that it works by limiting food intake rather than by malabsorption, but the overall weight loss is less than after other procedures. The gastric pouch fills quickly and empties slowly, giving a feeling of satiety. The disadvantage is that poorly motivated patients may opt for high-calorie drinks. In addition, with excessive food intake it is possible to enlarge the proximal gastric pouch. This operation went out of favour with the advent of the adjustable gastric band, which is more suitable for a laparoscopic technique. Although the operation is now seldom performed, patients who have undergone this operation may still present with the need for revision surgery. They have a circular stapled opening through both the anterior and posterior walls of the stomach. From this circular stapled opening there is a linear staple line to the angle of His and a band of polypropylene mesh wrapped around the lesser curve, restricting the outflow from the proximal gastric pouch to the rest of the stomach (Figure 18.8).

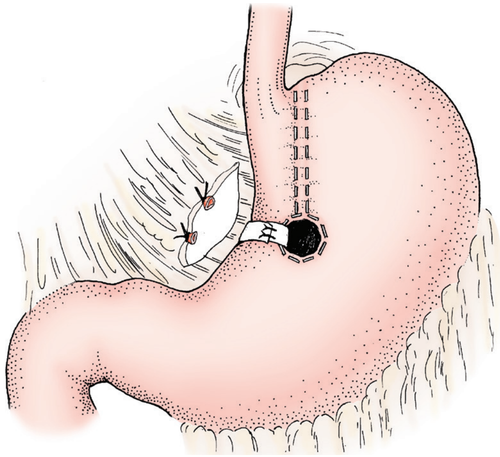

Figure 18.8 *Vertical banded gastroplasty.*

ADJUSTABLE GASTRIC BAND

The adjustable gastric band technique was developed from the vertical banded gastroplasty, over which it has several advantages. It is a more suitable operation for a laparoscopic approach and the band is adjustable, which allows the outlet diameter from the gastric pouch to be varied according to patient needs. The band can also be easily removed and no anatomical changes have been made that might interfere with future bariatric procedures.

Laparoscopic access is established in a similar manner to that described in Chapter 17 for other oesophagogastric junction procedures. A calibration tube with an inflatable balloon can be a useful guide. The tube is inserted into the stomach, the balloon filled with 15 ml of saline and the tube is then retracted until the balloon lies just below the oesophagogastric junction. The gastrohepatic ligament is opened alongside the proximal lesser curve and the dissection continues behind the stomach towards the angle of His, creating a retrogastric tunnel. The gastric band is then introduced from the angle of His, brought through the perigastric opening and around the stomach. It is then locked in place around the distal end of the calibration tube beyond the balloon (Figure 18.9). The band can then be secured to the anterior wall of the stomach with interrupted sutures. The tubing between the band and the reservoir is brought out through a port site. The reservoir, or access port, is placed at a site that allows easy access for percutaneous volume adjustments. A small incision is made and the reservoir is placed directly on the rectus sheath, to which it is now sutured. The tightness of the band is adjusted according to the patient's weight loss, with larger volumes of saline resulting in a smaller stoma and more restriction of intake.

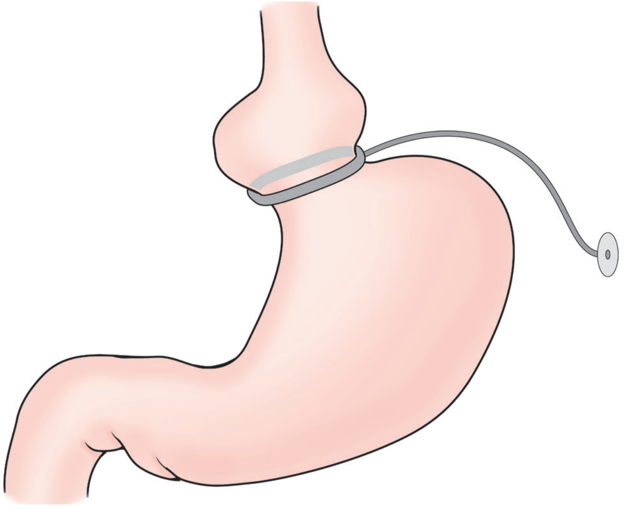

Figure 18.9 *Adjustable gastric band.*

Long-term complications include infection, band slippage and erosion of the band into the stomach.[9] Band slippage may lead to potentially fatal gastric ischaemia. If deflation of a slipped band does not relieve dysphagia or epigastric pain, emergency removal needs to be considered.

SLEEVE GASTRECTOMY

In this operation the fundus and the greater curve of the stomach are resected, leaving only sufficient lesser curve to close as a tubular 'sleeve' between the cardia and the antrum. The operation was originally conceived as a restrictive component of the biliopancreatic diversion and duodenal switch operation and the extent of the gastric resection is shown in Figure 18.13. It has, however, proved to be effective on its own and is gaining popularity as a first-line treatment. It has the advantage that if weight loss is either insufficient or not maintained, it is straightforward to proceed to a Roux-en-Y bypass or a switch procedure.

The operation is routinely performed laparoscopically. Similar laparoscopic access is required as for a gastrectomy. The greater curve is mobilised, securing all the gastric branches from the gastroepiploic arcade. A bougie is pressed up against the lesser curve and the sleeve created alongside the bougie by multiple firings of a linear stapler, starting in the gastric antrum. All stomach to the left of this staple line is excised.

JEJUNOILEAL BYPASS

The jejunoileal bypass was one of the first operations for morbid obesity, and relied on malabsorption as its principle. The jejunum was divided, usually 25 cm from the duodenojejunal flexure. The distal end was closed and the proximal end anastomosed end-to-side to the ileum, approximately 50 cm from the ileocaecal valve (Figure 18.10). The patient had a functional 'short bowel syndrome', combined with a blind loop of small bowel, which was exposed to neither bile nor food. While the weight loss was dramatic, long-term complications were unacceptable. Many patients developed liver cirrhosis secondary to the increased endotoxin load from the bacterial colonisation of the bypassed segment. This operation was, however, the forerunner of the later more sophisticated bypass operations.

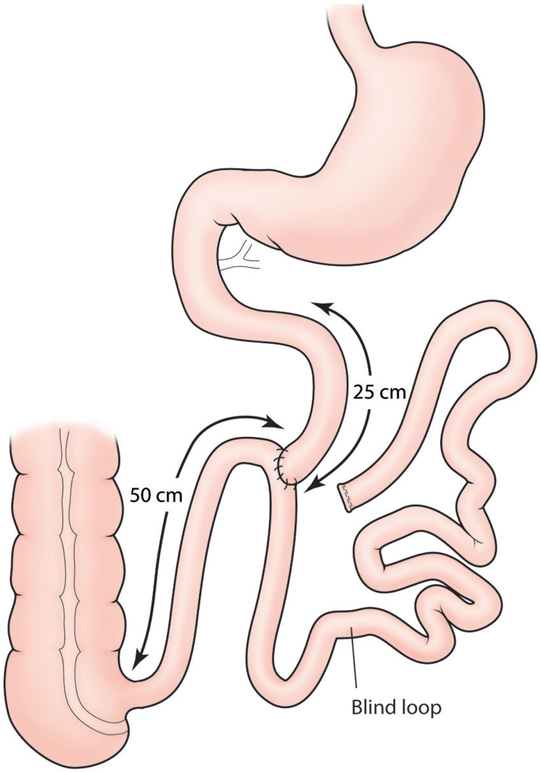

Figure 18.10 *The original jejunoileal bypass, which created a functional short bowel and a long blind loop.*

ROUX-EN-Y BYPASS

In the Roux-en-Y gastric bypass (Figure 18.11) the small upper gastric pouch, drained by the Roux loop, is predominately a restrictive operation. In addition, there is a prolonged reduction in appetite from changes in gut hormones[10] and also the patient is usually dissuaded from supplementing a reduced solid intake with high-calorie drinks, as these are likely to cause 'dumping'. This surgery is now usually performed laparoscopically but can be technicaly demanding. The procedure varies between surgeons, particularly in the order of dissection, the route chosen for the Roux loop and the technical aspects of anastomosing it to the upper gastric pouch. However, the description of the open procedure below summarises the basic steps. The oesophagogastric junction is mobilised. A retrogastric tunnel is created, starting from the gastrohepatic omentum, close to the lesser curve and emerging lateral to the angle of His. A small drain is passed through the tunnel to encircle the stomach and is used as a landmark for the creation of an upper gastric pouch using linear staplers. The jejunum is transected approximately 40 cm beyond the ligament of Treitz, with the distal divided end anastomosed to the proximal gastric pouch with

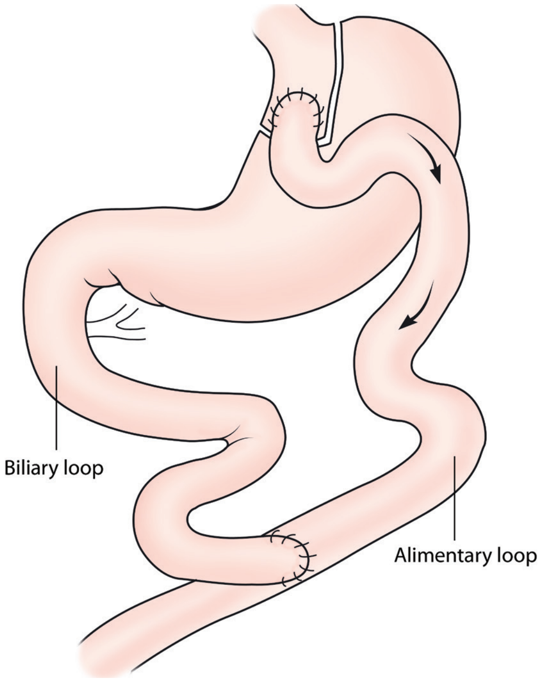

Figure 18.11 *A Roux-en-Y gastric bypass for morbid obesity. Modifications to the Roux loop, which shorten the common channel, introduce an additional malabsorptive component.*

a restricted stoma outlet of 1 cm. The Roux loop is completed by forming a jejunojejunostomy approximately 50 cm downstream. A greater weight loss can be achieved if a more distal loop of jejunum is used for the Roux loop or if the jejunojejunostomy is performed further downstream. These manoeuvres add an increasing malabsorptive component by decreasing the length of small bowel through which food must pass, and also by decreasing the common channel where bile, pancreatic juice and food can mix. This is a similar principle to that employed in the biliopancreatic diversion techniques described below. This combined restrictive and malabsorptive approach is particularly useful in patients with a BMI >50 kg/m^2 or in those who have failed to lose weight on a simpler procedure. Many variations of this procedure have been described.

BILIOPANCREATIC BYPASS

This operation was an attempt to overcome the metabolic disturbances associated with the early jejunoileal bypasses. A functional short bowel syndrome was still created, but a blind loop avoided as bile and pancreatic juice traversed the segment of small bowel that the food bypasses. It was normally combined with some form of gastric resection to add a restrictive component. Classically, a subtotal gastrectomy was performed, leaving a 200–400 ml remnant. The jejunum was transected 250 cm from the ileocaecal valve. The distal ileal limb was then anastomosed to the stomach remnant and the proximal ileal limb to the distal ileum some 50–100 cm upstream of the ileocaecal valve (Figure 18.12).

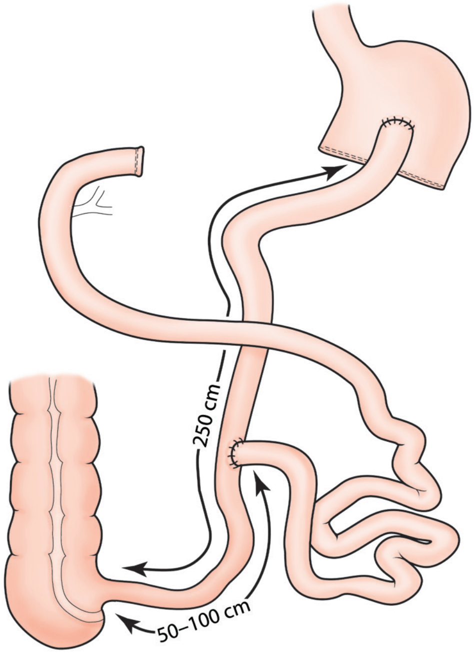

Figure 18.12 *Biliopancreatic bypass. In contrast to the original jejunoileal bypass, a blind loop has been avoided.*

BILIOPANCREATIC BYPASS WITH DUODENAL SWITCH

A biliopancreatic bypass is now commonly combined with a duodenal switch operation and this combination has in general replaced the biliopancreatic bypass from which it developed. A gastric sleeve has thus replaced the original upper gastric pouch as the restrictive element and most surgeons therefore favour a longer common channel, as the sleeve gastrectomy is a more restrictive procedure (Figure 18.13). It is a complicated operation but can now be performed laparoscopically.[11] Some bariatric units claim that both in terms of sustained weight loss and absence of functional and biochemical side-effects, it is a superior choice to a Roux-en-Y bypass, but it has found acceptance mainly in specialised units.

GASTRIC CANCER

Gastric cancer, despite a falling incidence in the Western world, is still a major cause of morbidity and mortality. In recent years the anatomical location of gastric cancer appears to have shifted from the antral portion to a more proximal part of the stomach, including involvement of the oesophagogastric junction. In Japan, gastric cancer is the commonest malignancy in both men and women, and this has led to the introduction of mass screening programmes to facilitate early detection. This approach appears to have successfully reduced mortality from the disease. *Early gastric cancer* is now defined as cancer restricted to the mucosa and

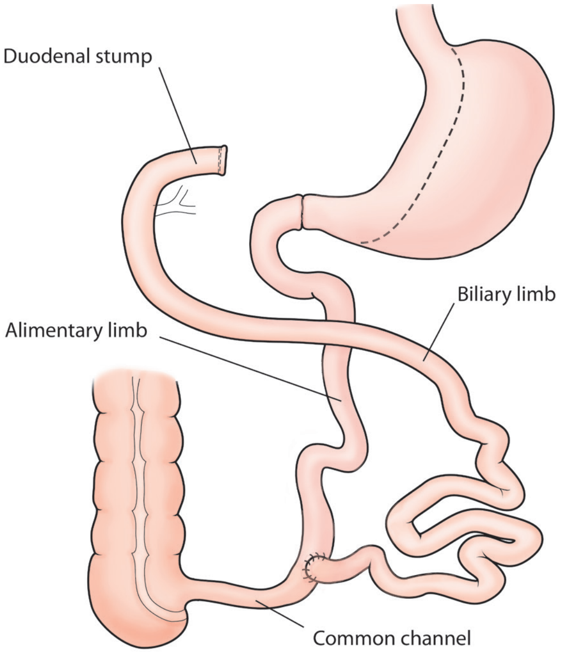

Figure 18.13 *Biliopancreatic bypass with a duodenal switch. The first part of the duodenum is transected and the distal end closed. The duodenum and jejunum form the biliary loop. A second division in the mid small bowel enables the distal divided end to be brought up and anastomosed to the proximal duodenum. The proximal divided end is then anastomosed end-to-side approximately 100 cm from the ileocaecal valve. The dotted line marks one type of gastric resection that can be combined with this procedure.*

submucosa (T1). Around one-third of Japanese patients are diagnosed at this stage as a result of extensive surveillance programmes.

Outcomes for patients who present with T2 disease and no evidence of metastatic spread are also good but, unfortunately, many patients present with more advanced disease. When a patient is diagnosed with gastric cancer, it must first be determined whether a potentially curative resection is possible. It is important to identify patients who will not benefit from any surgical intervention prior to a laparotomy. A CT scan is pivotal in preoperative staging as it may show liver or omental deposits or the involvement of preaortic nodes. Endoscopic ultrasonography is used in some centres to measure the depth of invasion and the involvement of adjacent nodes.

The management of all gastric cancers should now be with a multidisciplinary approach. Many patients will enter a palliative course after staging and those who come to a potentially curative resection will often be advised to have postoperative adjuvant chemotherapy.

DIAGNOSTIC LAPAROSCOPY

Diagnostic laparoscopy is particularly valuable in the identification of peritoneal seedlings and peripheral liver metastases that are too small to identify by CT scanning. This should ideally be performed several days prior to the intended surgery to allow time for pathological examination of suspicious lesions and cytological examination of ascitic fluid. At laparoscopy, the surface of the liver and the peritoneum over the falciform ligament and under the diaphragm should be examined carefully for peritoneal deposits. Any suspicious lesions should be biopsied and ascitic fluid sent for cytological examination to determine if malignant cells are present. While this places a further percentage of patients into a palliative category, it avoids unnecessary laparotomies and also helps to identify those with the greatest potential for surgical cure. Despite investigations, gastric cancer is understaged preoperatively in approximately 20 per cent of patients.

Radicality of surgery

The reasons why apparently curative resections fail must be explored whenever the radicality of a surgical excision is considered. For example, changes in surgical technique are most unlikely to reduce failure from haematogenous spread, but may reduce failure if recurrence occurs solely at the anastomosis, in the tumour bed or within the regional lymph nodes. Failure in gastric cancer occurs locoregionally, but also from dissemination throughout the peritoneal cavity and from blood-borne metastases.

EXTENT OF THE GASTRIC RESECTION

In early gastric cancer a conservative resection may be considered, but for most patients a subtotal or a total gastrectomy will be necessary for a potentially curative resection, with many tumours of the cardia requiring an additional distal oesophagectomy to achieve an R0 resection.

Subtotal or total gastrectomy

Gastric cancer spreads in the submucosal plane. At presentation, this infiltration may involve the whole of the stomach (linitus plastica), and in these cases the tumour infiltration may even extend into the duodenum or oesophagus. In most patients, however, there is a palpable edge to the tumour, and transection 5 cm clear of this edge will usually be free of tumour infiltration. Thus, in distal gastric cancer, a partial gastrectomy can offer an R0 resection. The proximal gastric remnant should include at least 2 cm of the lesser curve and the palpable edge of the tumour must therefore be 7–8 cm from the oesophagogastric junction. A total gastrectomy thus becomes necessary for any tumour that encroaches to within 7–8 cm of the oesophagogastric junction if positive resection margins are to be avoided. In theory, a proximal gastric cancer can be resected with adequate margins, and the antrum and pylorus preserved. However, functional results after a proximal subtotal gastrectomy and anastomosis of the distal stomach to the oesophagus are poor, mainly due to alkaline oesophageal reflux. Most surgeons recommend a total gastrectomy in these circumstances.

Limited excision of early gastric cancer

Most of the research on early gastric cancer and localised resection with curative intent has come from Japan. Endoscopic resection or laser ablation may be suitable for very superficial cancers. Resection techniques are superior as ablative procedures preclude any histological assessment. Endoscopic mucosal resection is performed via a two channel flexible endoscope. The lesion is lifted by submucosal saline injection, grasped with forceps and snared with a diathermy loop. The more accurate submucosal dissection on the surface of the muscle coat can be achieved under direct vision using an endoscopic electrosurgical knife.[12] Accurate preoperative assessment of the depth of invasion is crucially important as fewer than 5 per cent of mucosal cancers have nodal metastases, whereas in cancers that invade the submucosa, up to 25 per cent may have nodal metastases and around 5 per cent may have metastases in 2nd tier nodes. Limited full-thickness gastric resection, with sentinel node biopsy to exclude those requiring a more radical resection, is another option.[13]

THE EXTENT OF THE LYMPHADENECTOMY

Lymphatic spread can occur early in gastric cancer, and lymphatic recurrence in the gastric bed is a major area of failure. In some patients this occurs without simultaneous haematogenous or peritoneal spread, which raises the possibility that a more radical lymphadenectomy could have been curative. The Japanese have led the world in this concept and have extensively mapped the patterns of lymph node metastases. Gastric lymph nodes have been subdivided into numbered anatomical groups or 'stations' (Figure 18.14) and then considered as 'tiers' of nodes. The stomach is also subdivided into an upper section (C), a middle section (M) and a lower section (A). The tumour is then classified according to the section of stomach in which it arose and also any sections into which it has spread. For example, a localised antral tumour is designated 'A' and a middle-section tumour that has spread to the cardia 'MC'. The tiers of lymph nodes differ according to the position of the tumour. The 1st tier nodes are perigastric nodes close to the tumour and the 2nd tier nodes include both nodes along the proximal section of the arteries supplying the section of stomach involved in the malignancy and other more distant perigastric nodes. For example, stations 3, 4d, 5 and 6 are the 1st tier nodes for an antral cancer, and stations 7, 8, 9 and 1 are the 2nd tier nodes. The concept of a D1, D2 and a D2/D3 gastrectomy developed from this. A D1 gastrectomy implies the excision of all 1st tier nodes, a D2 gastrectomy the excision of all 1st and 2nd tier nodes, and a D2/D3 gastrectomy implies the additional removal of some 3rd tier nodes. The approach to lymphadenectomy in Japan became far more radical than in the West and very impressive survival figures were obtained. However, the true benefit from the more major surgery is less than it immediately appears. When a more radical lymphadenectomy is undertaken, metastases may be found in nodes that would not have been available for analysis after a standard, less radical operation. This places the cancer in a more advanced stage, and the apparent benefit from excision of more nodal tissue is then fallacious and merely a *stage migration phenomenon.*

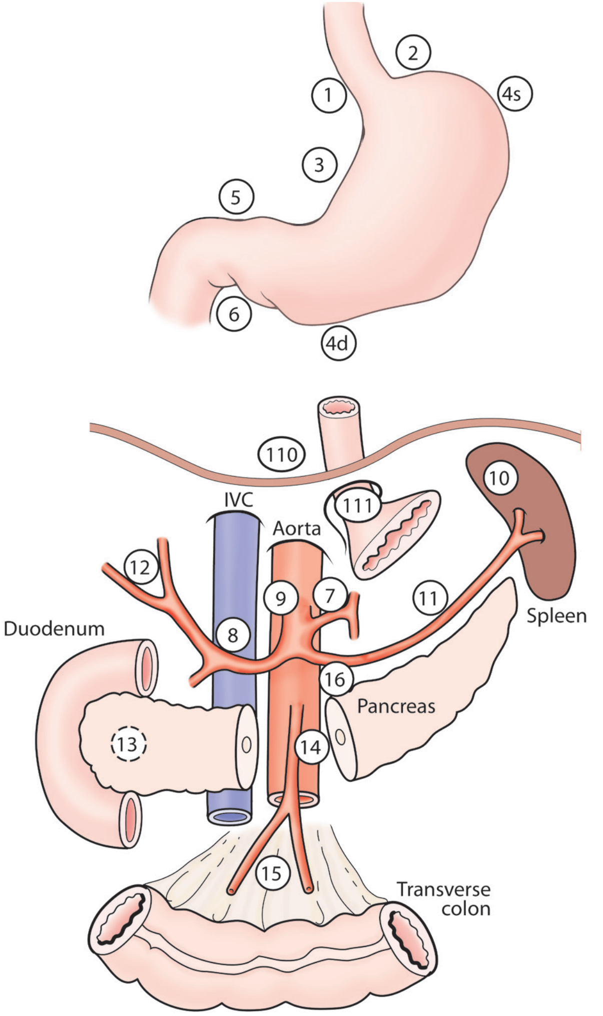

Figure 18.14 *Gastric lymph node stations. 1 = right cardiac; 2 = left cardiac; 3 = lesser curve; 4s = proximal greater curve; 4d = distal greater curve; 5 = suprapyloric; 6 = subpyloric; 7 = left gastric artery; 8 = common hepatic artery; 9 = coeliac axis; 10 = splenic hilar; 11 = splenic artery; 12 = hepatoduodenal; 13 = retropancreatic; 14 = root of mesentery; 15 = middle colic artery; 16 = para-aortic; 110 = para-oesophageal; 111 = diaphragmatic.*

The standard subtotal D2 gastrectomy for antral cancer, which excises all 1st and 2nd tier nodes, was described in Chapter 17 and is an operation that has been generally adopted. However, in proximal gastric cancer, which is much commoner in the West than in Japan, the 1st tier nodes are 1, 2, 3 and 4s and the 2nd tier nodes are 4d, 7, 8, 9, 10, 11, 5 and 6. Station 10 nodes are in the hilum of the spleen and station 11 are along the splenic artery, behind the pancreas. A full D2 gastrectomy for proximal cancer is, therefore, a very major procedure. It involves either the addition of a splenectomy and distal pancreatectomy or a difficult dissection if these nodes are to be retrieved but the organs retained. Data from the Dutch D1/D2 trial showed that D2 lymphadenectomy is associated with lower locoregional recurrence and gastric cancer-related death rates than is D1. However, data from the same trial showed that the D2 procedure was associated overall with significantly higher mortality, morbidity and reoperation rates. Any gain in long-term survival must be balanced against a higher perioperative mortality. However, as high-volume centres can offer a lower morbidity and mortality, at least partly associated with the highly specialised spleen-preserving D2 technique, a D2 lymphadenectomy is now the recommended surgical approach for patients with resectable gastric cancer.[14] The Italian analyses of their results has confirmed that in specialised centres the complication rates after D2 dissections are much lower than that reported from the original multicentre data and that early morbidity and mortality compare favourably with those after D1 dissections.[15]

The risk/gain balance for the individual node stations has also been calculated, and this may be more important than a rigid classification into node tiers. This calculation is based on the likelihood of metastases within the nodes of a particular station, the possible survival benefit from removing them and the additional mortality and morbidity from doing so. This has resulted in many surgeons performing the standard D2 subtotal gastrectomy for distal cancers with the additional removal of station 12 nodes (D2/D3 gastrectomy). Although these are 3rd tier nodes, they contain metastases in 9 per cent of distal tumours and 5-year survivals as high as 25 per cent have been reported from Japan in patients who have had positive station 12 nodes resected.

SEROSAL SPREAD

This is a common area of failure in gastric cancer, and the reason that laparoscopy should be considered as part of the staging procedure in order to save patients with macroscopic peritoneal deposits from non-curative major surgery. Most patients in the West present with gastric cancer that has invaded the serosa. The peritoneal cavity is already contaminated with malignant cells, even if there are no visible metastatic deposits, and this is reflected in a significantly worse prognosis. Most of the lesser sac peritoneum is excised in a D2 gastrectomy, and this may be of some value in posterior tumours that have only contaminated this area. Intraoperative and postoperative intraperitoneal chemotherapy may have a place when there is serosal invasion. In some units in Japan this is used routinely if peritoneal malignant contamination is confirmed by identification of free malignant cells on peritoneal cytology. However, the benefit of this approach either for positive cytology alone or for small peritoneal seedlings is still under review.

Adjacent organs can adhere to the involved serosa overlying a gastric cancer. This may be followed by direct tumour invasion. General peritoneal contamination will have been minimised by the malignant adhesions, but the prognosis is still poor. Extended excisions to include other organs invaded by the primary tumour are seldom justified.

Palliative surgery

The survival of patients in whom a curative resection is not possible is poor and in general, palliative surgery has a limited role. Chemotherapy can achieve a remission, with a reasonable quality of life, for a minority of patients.

If during the laparotomy conditions are discovered that preclude a curative resection, the surgeon must decide whether a palliative resection, a bypass or no further surgical procedure will offer the patient the best quality of life. This is a decision that had to be made frequently before preoperative staging was developed, and it may still be a common problem for surgeons with limited access to sophisticated imaging modalities. The surgeon must be careful not to be influenced by the understandable desire 'to do something', and the perception of failure if an 'open and close' laparotomy is chosen. The decision is not always straightforward.

PALLIATIVE RESECTION

This can offer the best palliation for a bleeding tumour, for gastric outflow obstruction and also for the non-specific, but distressing and unpleasant, symptoms associated with a fungating intragastric mass. It should certainly be considered for a small mobile distal tumour in a fit patient with a small metastatic load, especially as a palliative partial gastrectomy for malignancy does not need to include a radical lymphadenectomy. It should be remembered that if there is a heavy metastatic load, the mortality and morbidity of any major resection will be significantly increased. No anastomosis should be attempted through macroscopically malignant tissue and, if the tumour cannot be cleared with a partial gastrectomy, a total gastrectomy is seldom justified, as the quality of life with a total gastrectomy and metastatic malignancy is extremely poor.

BYPASS PROCEDURES

A gastroenterostomy can offer good palliation when an unresectable distal growth is causing a gastric outflow obstruction. This is often undertaken electively in patients whose cancers are known to be too advanced for curative surgery, but who have developed obstructive symptoms. However, the alternative of an endoscopic pyloric stent should always be considered. When the abdomen has already been opened and an unresectable tumour confined to the distal stomach is encountered, a gastroenterostomy is often justified even in the absence of established outlet obstruction, as there is a high risk of obstruction developing as the cancer advances. It is important to fashion the gastroenterostomy to a dependant part of the stomach, but as far from the tumour as possible to avoid later tumour obstruction of the anastomosis (see Chapter 17). A thorough abdominal examination should also be undertaken to determine the presence of peritoneal seedlings, which might cause a future small bowel obstruction. This complication may sometimes be avoided if a stenosing serosal secondary is removed as a wedge excision (see Chapter 22).

Proximal tumours can cause dysphagia, and they frequently present when they are locally irresectable or the patient already has metastatic spread. Palliative surgical bypass is seldom a practical option, but fortunately these growths can usually be stented endoscopically with relief of distressing symptoms.

Prophylactic surgery in hereditary diffuse gastric cancer

The presence of familial clusters of gastric cancer following an autosomal dominant pattern has been observed for many years. Surveillance has been unsuccessful, mainly because of the diffuse, submucosal nature of the cancer, which makes it undetectable despite repeated endoscopies. Most patients, even when under surveillance, present at an advanced stage with unresectable disease. The penetrance rate of the gene is reported at 70–80 per cent and, in the absence to date of a successful surveillance mechanism, a prophylactic total gastrectomy with Roux-en-Y reconstruction is a viable therapeutic option. However, the mortality and morbidity risk is not insignificant and genetic counselling in high-risk families is essential before offering any genetic testing.

When performing a total prophylactic gastrectomy for hereditary diffuse gastric cancer, it is imperative that all gastric mucosa is removed and that the transection is above the oesophagogastric junction and incorporates oesophageal squamous mucosa. This is confirmed intraoperatively by the pathologist with frozen-section examination. Any gastric mucosa left behind places the patient at a significant risk of cancer in the remnant tissue. Radical lymphadenectomy, which is usually associated with a total gastrectomy, is not required.

OTHER GASTRIC MALIGNANCIES

Gastrointestinal stromal tumours

Gastrointestinal stromal tumours (GISTs) are mesenchymal tumours of variable malignant potential and are most commonly encountered in the stomach. They were previously considered to be gastric leiomyomas or leiomyosarcomas (see Chapter 16). Although the tumour behaviour can be partially predicted histologically, this information is seldom available to the surgeon preoperatively. In general, a small tumour discovered as an incidental finding behaves in a benign fashion and the larger tumours, which present symptomatically, are usually more aggressive. Many patients present at an advanced stage with extensive disease, and there may also be peritoneal and liver metastases.

Despite investigations it is often not possible to establish the diagnosis preoperatively, especially as, if a curative resection is planned, it is important to avoid biopsy with the risk of spillage of tumour cells. A common presentation is as an emergency with haemorrhage and the bleeding is seen at endoscopy to be from an ulcer on the summit of a submucosal gastric mass. Complete surgical clearance is the main treatment objective, and this may require the removal of adjacent organs. Lymph node metastases are rare and lymphadenectomy unnecessary. Many patients who develop locoregional recurrence have successfully undergone further clearance, and follow-up is therefore essential. Tyrosine kinase inhibitors (for example imatinib) have proved effective in the treatment of unresectable or metastatic GISTs and have also been used in a preoperative setting to allow surgery in a previously unresectable situation (see also Chapter 16).

Gastric lymphoma

Low-grade lymphomas associated with *Helicobacter pylori* regress on irradication of the infection. High-grade lymphomas do not regress and are now treated with chemotherapy rather than resection, with surgery reserved for complications such as haemorrhage or perforation.

Gastric neuroendocrine tumours (carcinoids)

Small tumours associated with atrophic gastritis (type I) have a low malignant potential and can be removed by endoscopic resection. In multifocal disease, an antrectomy to reduce gastrin levels should be considered. Tumours associated with the multiple endocrine neoplasia syndromes (type II) are more aggressive, but management should focus on identification and treatment of the causative gastrinoma. The large rare sporadic gastric carcinoids (type III) are aggressive, fast growing and metastasise early. If metastases have not yet occurred, the treatment is a D2 gastrectomy.

MALIGNANT OESOPHAGEAL TUMOURS

Despite advances in care, oesophageal carcinoma still carries a poor prognosis, which is attributed to its aggressive biological nature and late presentation. The worldwide incidence of oesophageal adenocarcinoma is increasing and is now greater than that of squamous cell carcinoma. Adenocarcinoma predominantly affects the lower third of the oesophagus. Tumours at the oesophagogastric junction were previously somewhat artificially divided into either gastric or oesophageal tumours when only a centimetre or two separated them, but more recently they have been recognised as a single clinical entity.

The surgery of oesophageal cancer is extremely challenging. It has now generally been centralised within the UK to regional centres in an attempt to improve results, and this surgery is certainly no longer within the remit of the general surgeon without a subspecialty upper gastrointestinal cancer interest. Good results are only partly surgeon dependent, and a multidisciplinary team approach to oesophageal cancer is essential to identify patients who will benefit from neoadjuvant chemoradiotherapy, those who are suitable for surgery and those requiring palliative care. Successful oesophageal surgery is dependent not only on skilled anaesthesia and intensive care, but also on physiotherapy and nutritional support.

PREOPERATIVE INVESTIGATIONS

In the absence of a screening programme, many patients in the Western world present with dysphagia. Diagnosis is established by endoscopy, where tumour site and size are observed and a biopsy taken for pathological determination of histological type. No surgery or intervention should be considered in the absence of a histological diagnosis. CT staging of the thorax, abdomen and neck will provide critical information on associated lymphadenopathy or the involvement of adjacent organs, in addition to the detection of metastases. Bronchoscopy, once mandatory to rule out tracheal or bronchial extension of tumours in the upper two-thirds of the oesophagus, has now been superseded by the increased accuracy of CT imaging. Endoscopic ultrasonography is accurate in determining extramural extension and the degree of associated lymphadenopathy and MRI may give additional information when CT is inconclusive. Laparoscopy, as discussed under gastric cancer, is a useful staging modality in lower oesophageal cancers. Positron emission tomography (PET) scans may be helpful when selecting a potentially curable subgroup.

Principles underlying oesophageal cancer surgery

Oesophageal lymphatic drainage is into a submucosal and perioesophageal plexus, in which lymph mixes from all levels of the oesophagus before draining to regional nodes. This has two important implications for the surgeon.

First, the possibility of submucosal extension within the lymphatic plexus must be considered, as this affects the margins of resection required. Even with a 10-cm macroscopic clearance, 10–20 per cent of specimens will have involved margins. For this reason a total or subtotal oesophagectomy is recommended even for lower-third tumours. Lower-third adenocarcinomas may invade extensively into the stomach, and oesophagectomy may have to be combined with proximal partial or even a total gastrectomy, with or without splenectomy, to achieve an R0 resection. Similarly, oesophagectomy for a proximal oesophageal squamous cell carcinoma may have to be combined with a pharyngectomy to obtain complete local tumour clearance (see Chapter 10).

Second, this mixing of lymph before drainage to nodes makes any form of very limited lymphadenectomy of little value. Debate continues over the survival advantages of a formal, more extensive lymphadenectomy. The lymphatic drainage from the oesophagus is divided into three fields: the abdominal, the intrathoracic and the cervical:

- A *one-field lymphadenectomy* involves resection of the intra-abdominal nodes draining the proximal stomach and distal oesophagus. This follows similar principles to the D2 lymphadenectomy described for proximal gastric cancer.
- A *two-field lymphadenectomy* describes the additional clearance of the intrathoracic nodes. These include the nodes in the tracheal bifurcation, the right paratracheal nodes and the pulmonary hilar nodes, in addition to the para-oesophageal and the para-aortic mediastinal nodes.
- A *three-field lymphadenectomy* includes, in addition, a neck dissection to clear the brachiocephalic, deep lateral and external cervical nodes.

While some surgeons recommend a formal two-field lymphadenectomy, others believe that positive nodes are mostly an indicator of incurable disease. A more extensive lymph node dissection improves staging, but the stage migration phenomenon, as discussed above for gastric cancer, makes it more difficult to interpret by how much locoregional control and survival are also improved. There is also the issue of increased morbidity and mortality associated with a more major operation.

Surgery should be tailored to offer a patient the procedure that achieves minimal morbidity and mortality, but allows macroscopic and microscopic clearance. The choice of operative intervention depends on a number of factors including tumour type, location, extent of lymph node involvement, fitness for surgery and surgeon preference. Resections are almost always carried out with curative intent. However, some patients who have involved margins (R1 resection) have good local disease control but die of distant disease before the tumour recurs locally.

Surgery for oesophageal cancer necessitates access to both the abdomen and the chest. Abdominal access is needed for dissection of the abdominal nodes and for preparation of the stomach as an oesophageal replacement. Thoracic access is needed for dissection around the primary tumour and the macroscopically normal proximal and distal oesophagus to be excised, in addition to any thoracic node dissection. Increasingly, minimal-access approaches to either the abdominal or the thoracic resection, or to both, are under development in specialised centres. The three more classic surgical approaches to oesophagectomy were described in Chapter 17 and each of these has both advantages and disadvantages.

Transhiatal approach

The transhiatal approach involves only abdominal and cervical incisions. The patient does not have to be repositioned during surgery, the operative time is reduced, a thoracotomy is avoided and the procedure is thus associated with less cardiorespiratory dysfunction. This is the ideal approach for patients with respiratory co-morbidity. Additionally, a cervical anastomotic leak is preferable to an intrathoracic leak.

However, patient selection is critical to outcome. The transhiatal approach is most suitable for cancers involving the distal oesophagus and is unsuitable for tumours that are large and those that may have extensive extramural spread, involving adjacent organs such as the aorta or tracheobronchial tree. Particular care should be taken in selecting any middle-third tumour for this technique, as here it is only suitable for tumours that are confined to the oesophageal wall. Additionally, surgeons should be aware that fibrosis secondary to adjuvant therapies may make blunt dissection difficult and more hazardous. Damage can occur during blunt dissection to intrathoracic vessels, the trachea and the recurrent laryngeal nerve. Another objection to transhiatal oesophagectomy is the quality of oncological clearance, given that much of the dissection is blunt and performed blindly, with a lower yield of lymph nodes compared with the thoracic approach. Despite the theoretical advantages of a formal lymphadenectomy, continuing trials have shown no significant differences in long-term survival between the transhiatal and transthoracic approaches.

Thoracoabdominal oesophagectomy

Excellent access is obtained both to the infra-aortic oesophagus and to the stomach, without the necessity of moving the patient during the operation. The standard technique, however, necessitates an anastomosis below the aortic arch, thus restricting the radicality of the oesophageal resection. Lymph node dissection may not be so radical as when the oesophagus is approached from a right thoracotomy. The incision, which crosses the costal margin, is associated with significant postoperative respiratory morbidity.

Several adaptations to the old thoracoabdominal technique have been developed. It can be combined with a cervical incision both to increase the length of oesophagus removed and to carry the anastomosis into the neck. A left thoracotomy combined with a transhiatal approach to the stomach is a variant of the left thoracoabdominal approach, and may be associated with a lower morbidity. This was the standard approach for a large series from China.[16]

Ivor Lewis and McKeown oesophagectomies

These two- and three-stage oesophagectomies allow direct visualisation of the whole length of the intrathoracic oesophagus, facilitating a more extensive thoracic lymphadenectomy. These approaches are particularly suitable for large mid-oesophageal tumours that have breached the oesophageal wall and may lie in close proximity to adjacent structures. They may also be the safest option for patients who have had preoperative chemoradiotherapy, which potentially limits oesophageal mobilisation. In the Ivor Lewis operation an intrathoracic anastomosis is performed; this is less likely to leak than a cervical anastomosis, but the consequence of a leak is much more serious. In the three-stage McKeown oesophagectomy a third incision is made in the neck. The anastomosis in the neck is not only safer than in the thorax but also allows a greater length of oesophagus to be removed. However, the risk of recurrent laryngeal nerve damage is increased when there is an additional cervical incision.

The main disadvantage of these operations is the morbidity associated with a thoracotomy. In addition, the patient must be turned during the operation as there is no access to the gastric cardia from the right thorax. A more modern variation on the McKeown technique involves performing the right thoracotomy first. Once intrathoracic oesophageal mobilisation is complete, the thoracotomy is closed and the remainder of the operation performed in a similar fashion to that described for transhiatal oesophagectomy through upper abdominal and left cervical incisions. This is thought to reduce the respiratory insult, but the benefit of the initial laparotomy to check for disseminated tumour is lost. A preoperative laparoscopy may therefore have an important place, particularly when this modification is planned for a distal oesophageal tumour.

Endoscopic treatment of early oesophageal cancer

Endoscopic ablation techniques have been undertaken in Barrett's oesophagus for many years and have been curative sometimes even when there is an early adenocarcinoma. Submucosal endoscopic resection is more precise and allows histological assessment of depth of invasion, tumour margin clearance and adjacent mucosal dysplasia. It is now an established option in high-grade dysplasia and intramucosal adenocarcinoma associated with Barrett's oesophagus.[17] However, in both Barrett's oesphagus and early squamous cell lesions there is field change and local recurrence is likely, but the greater concern is possible node involvement, particularly if there is any submucosal invasion. Selection depends on very accurate preoperative staging of depth of invasion and a reassessment of the advisability of an oesophagectomy if submucosal invasion is shown on histology. The desire to avoid major surgery in an unfit elderly patient is almost always justified, but it must be remembered that if the patient proves to have had nodal involvement, the opportunity to intervene for cure will have been lost.

Neoadjuvant therapy for oesophageal cancer

For oesophageal adenocarcinoma, there is strong evidence that preoperative chemoradiotherapy improves long-term survival compared with surgery alone. Perioperative chemotherapy (combined pre- and postoperative) is the preferred option for oesophagogastric junction adenocarcinoma. For oesophageal squamous cell carcinoma, there is no evidence to support the use of preoperative radiotherapy. However, chemoradiotherapy alone has a role in the treatment of localised squamous cell carcinoma of the proximal oesophagus. Squamous cell carcinoma of the middle or lower third of the oesophagus may be treated with chemoradiotherapy alone or chemoradiotherapy followed by surgery. There is no evidence to support the routine use of postoperative chemotherapy in squamous cell carcinoma of the oesophagus.[18]

Palliative management of oesophageal and oesophagogastric junction tumours

In the absence of any screening programmes, a high proportion of patients with gastric and oesophageal carcinomas present with advanced unresectable disease. Their management is principally palliative, aimed at symptom control. Some patients, despite having early cancer, may be unsuitable for radical surgery due to co-existing morbidity, and this subgroup also have to be managed in a palliative manner.

In patients with unresectable and metastatic disease the addition of chemotherapy may prolong survival, but this must be weighed against the patient's fitness for such treatment and the quality of life obtained. Radiotherapy may also be used to ameliorate pain from metastatic bone disease. However, the predominant and most distressing symptom for patients with advanced oesophageal and proximal gastric cancer is dysphagia. Fortunately, there are several effective palliative options. A tumour can be stented, reduced in bulk or bypassed. Non-surgical debulking of a tumour can be achieved by a variety of methods, either in conjunction with a stent or as an alternative if stent insertion is not possible.

Oesophageal stents will usually enable a patient to resume a liquid or semi-solid diet. In principle, a soft guide-wire, followed by a self-expanding stent, is placed through the lumen of the tumour under radiological control or endoscopic visualisation. Oesophageal stent insertion may not be possible if the patient has a proximal oesophageal tumour near the cricopharyngeal sphincter.

Palliative radiotherapy is effective but initially dysphagia may be exacerbated by oedema and no benefit seen for up to 2 months. External beam radiotherapy will require multiple visits to hospital for the most effective fractionated regimes. Brachytherapy, which involves the placement of a radioisotope within the lumen of the tumour, is another option. Inherent risks of radiotherapy include the development of a tracheo-oesophageal fistula and stricture formation.

Laser destruction of exophytic tumours can effectively palliate dysphagia, but its use has been largely superseded by stents.

Photodynamic therapy relies on intravenously administered photosensitisers, which are taken up selectively by malignant cells, where they are then activated by light. Oxygen free radicals are generated, which induce tumour necrosis. The photosensitive agent is retained in tissues for several weeks and sunburn is a common complication of this procedure.

Surgical bypass carries a significant risk, although it is a very effective method for alleviating dysphagia. It is also a useful procedure in the management of tracheo-oesophageal fistulae associated with oesophageal cancer or in its treatment. Either a gastric or a colonic conduit is suitable, and this must often be brought up by an extra-anatomical route (see below).

TRACHEO-OESOPHAGEAL FISTULAE IN OESOPHAGEAL CANCER

An acquired tracheo-oesophageal fistula is almost always secondary to direct invasion by a primary or secondary tumour or it occurs as a complication of the treatment of a malignancy, which is most often an oesophageal tumour. The fistula may arise spontaneously with tumour advancement or it may occur following oesophageal surgery or radiotherapy. The patient presents with extreme respiratory compromise and recurrent pulmonary infections, and despite aggressive intervention the condition is often fatal. The diagnosis can be confirmed by instillation of a water-soluble contrast medium into the oesophagus. The fistula may also be visualised by endoscopy or bronchoscopy, which helps to determine if there is a malignant cause for the communication. Acquired tracheo-oesophageal fistulae will not close spontaneously and require operative intervention if the patient is stable. In critically ill patients, oesophageal ligation, with the creation of a high oesophagostomy and a gastrostomy, may offer the best outcome. If the fistulation is due to a primary or secondary malignancy, management is principally palliative aimed at symptomatic relief.

Aggressive operative intervention should be considered in patients who have a fistula as a complication of oesophagectomy performed for an early cancer and also in those who have had a complete pathological response following radiotherapy. High fistulae may be approached via a low collar incision. Fistulae at the level of the carina require a lateral thoracotomy for access. If the fistula is small, it may be divided and the oesophagus and trachea closed primarily. In the neck the strap muscles are mobilised and placed between the oesophagus and trachea to buttress the closure, thus reducing the potential for breakdown and recurrence. In the thorax the closure can be protected with a pleural and intercostal muscle flap. Large fistulae may require tracheal resection and reconstruction. When a tracheo-oesophageal fistula occurs as a complication of oesophagectomy, the gastric tube may have to be removed and an interposition graft, using colon or jejunum, fashioned. Bronchial stents may also be of benefit in certain circumstances.

OPERATIVE MANAGEMENT OF COMPLICATIONS OF UPPER GASTROINTESTINAL SURGERY

Haemorrhage

EARLY POSTOPERATIVE HAEMORRHAGE

Intraluminal haemorrhage after a gastric resection or anastomosis is usually due to bleeding from a suture line. The patient may have melaena or have fresh blood in the nasogastric tube. Most bleeding is self-limiting and settles spontaneously, but if the bleeding is excessive or persists, then an endoscopy should be performed. Minimal insufflation is used and diathermy should be avoided if the primary anastomosis was formed using staples. If endoscopic control of significant bleeding is unsuccessful, then reoperation is mandatory.

In patients who have had a subtotal gastrectomy, a transverse incision is made in the stomach remnant just above the anastomosis. Alternatively, existing suture lines, such as a gastrojejunal anastomosis or a pyloroplasty, are reopened. Following gastric aspiration and washout, a bleeding point can usually be identified, which can then be controlled by undersewing the vessel. Occasionally, the bleeding point is from a duodenal ulcer, which will require an anterior duodenotomy to provide adequate access. There should be no hesitation in deciding to convert a Billroth I to a Billroth II anastomosis if there is difficulty in controlling a duodenal bleed.

A major intraperitoneal bleed most commonly results from an unrecognised splenic injury or a ligature that has slipped from a gastric vessel. Laparotomy for control of haemorrhage is indicated. Mediastinal bleeding may be from the azygos vein or from oesophageal branches of the aorta. Even when the original oesophageal dissection has been performed transhiatally, access to deal with this emergency will require a thoracotomy.

SECONDARY HAEMORRHAGE

This usually occurs around 2 weeks after surgery and is associated with intra-abdominal sepsis. The tissue is friable and any bleeding vessel is difficult to secure. As discussed in Chapters 1 and 15, interventional radiology and embolisation may be a better solution than surgery. However, the haemorrhage may be sudden and torrential, and immediate laparotomy may then be the only option. A supracoeliac aortic clamp will sometimes provide temporary control in this situation (see Chapter 7).

Anastomotic failure

Anastomotic failure presents as a wide range of clinical scenarios. At one end of the spectrum is a patient who is clinically well but has a subclinical leak with radiological evidence of extravasation of contrast. At the other end of the spectrum is a patient who is profoundly unwell and in whom the gastric remnant or the oesophageal conduit that has been used for the anastomosis has necrosed.

ISCHAEMIC NECROSIS OF THE GASTRIC REMNANT OR CONDUIT

Proximal gastric remnant

This serious complication of a distal gastric resection is fortunately uncommon. Predisposing factors include ligation of the left gastric artery, combined with excessive mobilisation of the greater curve with compromise of the blood supply from the short gastric vessels, particularly in association with a splenectomy. If the entire remnant has necrosed, then a completion gastrectomy with a Roux-en-Y reconstruction will be required. If the ischaemia extends to the distal oesophagus, then a primary anastomosis is problematic. A cervical oesophagostomy is performed, with colonic or jejunal interposition reconstruction at a later stage.

Gastric, colonic or jejunal conduit

The blood supply of the stomach, which has been mobilised to bring it up for an anastomosis to the proximal oesophagus, is vulnerable. Alternative oesophageal conduits are similarly vulnerable. Postoperative ischaemic necrosis of a conduit is associated with a high mortality, not least as surgical intervention in the form of a thoracotomy is usually necessary. The necrotic part of the conduit is resected and the viable portion closed and returned intra-abdominally. A cervical oesophagostomy is then performed with future reconstruction possible if the patient survives.

ANASTOMOTIC DEHISCENCE

The presentation of anastomotic dehiscence is varied. Patients may have systemic sepsis from thoracic or peritoneal soiling, or a minor leak may only be demonstrated on contrast imaging. An anastomotic leak in the neck will usually present with localised sepsis or the development of a fistula. Subclinical leaks will usually settle if commencement of oral intake is postponed. Generalised peritonitis or mediastinitis will require reoperation, but with the advancement of radiological techniques the vast majority of localised abdominal and thoracic abscesses secondary to minor anastomotic leaks can be successfully managed with antibiotics and percutaneous drainage. If the expertise is available, a covered stent, placed endoscopically across an anastomotic leak, is finding an increasing role in management. When it is necessary to re-explore the abdomen or chest, great caution must be exercised, as often the tissues are oedematous, friable and prone to bleeding. Abscesses are drained and any anastomotic breakdown defunctioned by fashioning an appropriate stoma. Re-suturing a leaking anastomosis in the presence of contamination is not recommended.

Oesophageal anastomotic leakage

Oesophageal anastomotic leakage is a challenging complication and the potentially lethal consequences of an intrathoracic anastomotic dehiscence led to an upsurge in popularity of transhiatal oesophagectomy with a cervical anastomosis. If there is an anastomotic leak from an intrathoracic anastomosis, image-guided drainage and a transanastomotic covered stent may be employed. Successful management should also include prompt control of sepsis. When reoperation is necessary, the anastomosis may need to be taken down with the formation of a cervical oesophagostomy and the return of the stomach to the abdomen. PEG feeding has then to be continued until the patient is fit enough for an oesophageal conduit to be considered. While recent advances in surgical and endoscopic techniques have improved prognosis for these patients, overall mortality still ranges from 20 to 50 per cent.

While the leak rate for cervical anastomosis is higher, it is associated with a better outcome. It can be treated conservatively or the wound opened, irrigated and left on free drainage. The patient is commenced on jejunostomy feeding and is usually allowed oral fluids within a few days. Occasionally, the cervical anastomotic breakdown is associated with major ischaemia, requiring a more extensive reoperation.

Duodenal stump blow-out

Duodenal stump blow-out is a life-threatening complication that may occur following any procedure that involves division and closure of the duodenum, as in a Billroth II or a total gastrectomy. An ultrasound scan may identify a fluid collection in the region of the duodenal stump, and aspiration of the collection confirms bile. Small collections may be managed by percutaneous radiological drainage in combination with broad-spectrum antibiotics and parenteral nutrition. If radiological drainage is unavailable or is unsuccessful, then surgery is necessary. Unfortunately, on re-entering the abdomen there is often considerable inflammation and sepsis with anatomical distortion. Primary closure is not safe in this hostile environment. Instead, a controlled fistula should be created (see Figure 18.4). A distal feeding tube to enable enteral nutrition is important for postoperative recovery. Octreotide may reduce the fistulous output. An adequately drained controlled duodenal fistula will usually heal unless there is local infection, mechanical obstruction of the afferent limb, associated pancreatitis or a persistent duodenal ulcer.

Acute gastroparesis

Many patients, following upper gastrointestinal tract surgery, have a degree of gastric atony that generally recovers within 10–12 days. Delayed gastric emptying may also occur secondary to stomal oedema. Conservative management consists of nasogastric tube insertion to decompress the stomach, correction of electrolyte imbalances, maintenance of nutrition and the use of prokinetics, such as erythromycin. Persistent symptoms for more than 4 weeks should raise the possibility of an underlying mechanical problem, which may need surgical intervention.

Chylous leak

Chylothorax is a collection of chyle within the mediastinum or pleural cavity. It occurs following damage to the thoracic duct or right bronchomediastinal trunk. Often there is a delay of up to 10 days between the time of injury and onset of symptoms. Persistent output from the chest drain following an oesophagectomy or the development of a pleural effusion, usually on the right, should arouse suspicion. Biochemical analysis of the pleural aspirate will confirm a high triglyceride and chylomicron content. Chylothorax carries a mortality rate of 30 per cent and must be actively managed.

Conservative management

Conservative management, which includes total parenteral nutrition in addition to *somatostatin* to reduce chylous output, has a success rate of approximately 50 per cent. High-volume iatrogenic chylothorax – defined as over 1 litre of chyle produced each day for 4–6 days – is most unlikely to respond to conservative management, and the patient becomes progressively metabolically and nutritionally compromised. Early surgery is therefore recommended for these high-volume leaks. A smaller-volume leak that has persisted for over 2 weeks is another indication to consider surgical intervention.

Surgical intervention

At re-exploration there are two main choices. The thoracic duct can be ligated just above the diaphragm or, alternatively, the laceration can be localised and repaired. Preoperative administration of cream via the nasogastric or feeding jejunostomy tube will increase the production of chyle and may help in identification of the injured duct. The use of methylene blue dye is not recommended because of tissue staining, which interferes with visualisation. Some centres recommend that if surgical intervention for a persistent chylous leak is required, the transabdominal approach is better.[19]

Late complications of gastric surgery

Adhesion obstruction can follow any intra-abdominal surgery, but intestinal obstruction from internal herniae can be difficult to unravel, especially after some of the more complex operations for morbid obesity. Routine endoscopic access to upper gastrointestinal haemorrhage or common bile duct stones may also be no longer possible.[9] Both resectional and non-resectional gastric surgery create permanent changes in gastrointestinal function. Some of the adverse consequences of these changes can be modified by further surgical intervention.

ALKALINE REFLUX GASTRITIS

Reflux of alkaline intestinal contents, particularly bile, into the stomach causes mucosal damage. Enterogastric reflux is most common after a Billroth II gastrectomy or a gastroenterostomy. Further reflux into the oesophagus can then cause an alkaline oesophagitis. Conservative management, including the use of bile-sequestering agents, provides little symptomatic relief, but further surgery can be very effective.

In patients who have had a truncal vagotomy with gastroenterostomy, the simplest solution is to take down the gastroenterostomy. Gastric stasis is seldom a problem if more than a year has elapsed since the initial surgery, as poor post-vagotomy gastric tone improves with time, but there is a risk of recurrent duodenal ulceration if the original vagotomy was incomplete. Reversal of the gastroenterostomy is contraindicated if there is any stenosis of the pylorus. Instead, an antrectomy with a Roux loop reconstruction should be considered.

After a Billroth II gastrectomy, alkaline reflux oesophagitis can be relatively simply treated by the conversion of the gastric drainage to a Roux-en-Y gastrojejunostomy (Figure 18.15). The Roux limb directs the alkaline contents 45–60 cm beyond the gastric remnant, thereby reducing the potential for bile reflux. However, this is an ulcerogenic manoeuvre, as it diverts the buffering effect of the alkaline gastrointestinal secretions from the gastroenteric anastomosis. This is an important consideration if no vagotomy was performed and the gastrectomy was relatively conservative, with retention of much of the parietal cell mass. The addition of a vagotomy should therefore be considered, especially if the original operation was for peptic ulceration.

Enterogastric reflux can also occur in a retrograde fashion when the pyloric sphincter has been destroyed by a pyloroplasty or has been excised and continuity restored by a Billroth I anastomosis. Reversal of a pyloroplasty is relatively straightforward and may be successful. The time that has elapsed since the surgery must again be considered. If the pylorus is too scarred to be reconstructed, an antrectomy with a Roux loop reconstruction is again the favoured option if the original operation was a vagotomy and pyloroplasty. When the previous surgery was a Billroth I gastrectomy, this can be revised to a Roux loop anastomosis. The loss of buffering alkali to this anastomosis must again be considered. One manoeuvre for achieving Roux loop drainage without taking down the original anastomosis is with the De Meester duodenal switch procedure, which is illustrated in Figure 18.16. This can also be a useful operation for alkaline reflux gastritis and oesophagitis, which can be particularly troublesome after an oesophagectomy that was combined with a proximal partial gastrectomy.

Interposition of an isolated isoperistaltic jejunal loop as a spacer between the gastric remnant and duodenal stump has also been used to reduce bile reflux after a Billroth I gastrectomy.

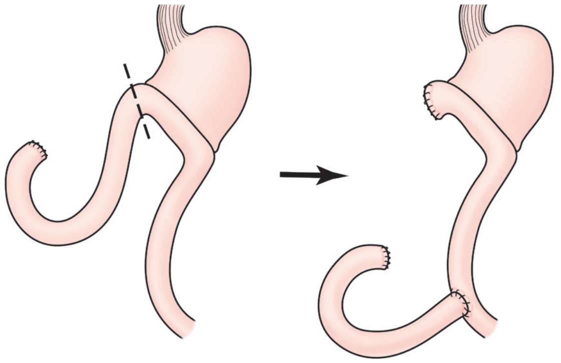

Figure 18.15 *A Billroth II (Polya) anastomosis can be easily converted to a Roux loop.*

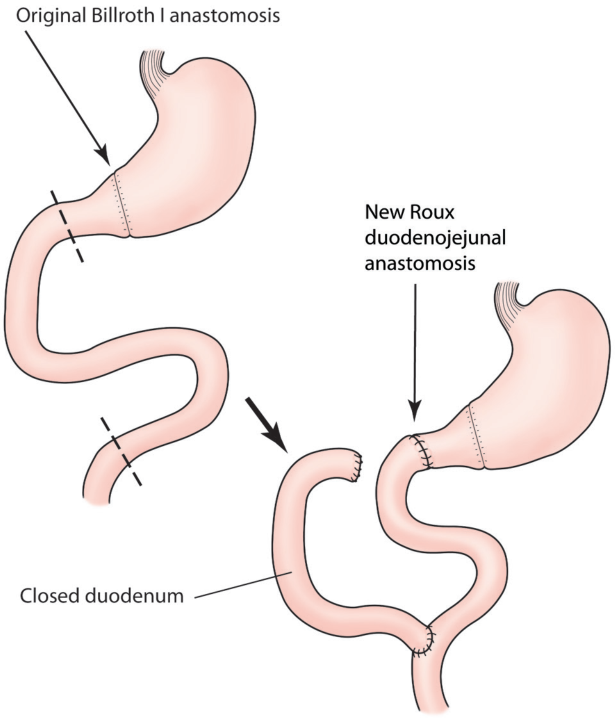
Original Billroth I anastomosis
New Roux duodenojejunal anastomosis
Closed duodenum

Figure 18.16 *De Meester duodenal switch operation after a previous Billroth I gastrectomy.*

DUMPING SYNDROME

This is one of the commonest complications of gastric surgery and is partly the result of the lack of an effective pyloric sphincter to control delivery of a glucose-rich meal into the small intestine. However, the coeliac branch of the vagus nerve has also been implicated and its preservation has been shown to reduce dumping.[20]

Early dumping occurs within a few minutes of the meal, as the hyperosmolar intestinal contents cause significant fluid shifts into the intestinal lumen. This results in epigastric pain and explosive diarrhoea in association with systemic vasomotor symptoms secondary to the hypovolaemia.

Late dumping occurs several hours after a meal. The large glucose load presented to the small intestine causes hyperglycaemia, followed by a compensatory hyperinsulinaemia, which then results in a later hypoglycaemia and associated systemic symptoms.

The majority of these patients respond to dietary manipulation that consists of small-volume, frequent meals, which are low in refined carbohydrate. Octreotide, when taken preprandially, is associated with a significant improvement in vasomotor and gastrointestinal symptoms. If symptoms persist, surgical intervention should be considered to slow the delivery of gastric contents into the bowel. The reconstruction of a pylorus after a pyloroplasty or the dismemberment of a gastroenterostomy as described above can be successful. The conversion from a Billroth I or Billroth II reconstruction to a Roux-en-Y loop may be effective, as it slows the delivery of gastric contents into the small bowel.

AFFERENT AND EFFERENT LOOP SYNDROMES

Afferent and efferent loop syndromes occur secondary to partial or complete loop obstruction.

Afferent loop syndrome may present acutely early in the postoperative period following a Billroth II gastrectomy or a Roux loop reconstruction, and is a surgical emergency. The closed loop is at imminent risk of perforation, usually as a duodenal stump blow-out. There may be an associated rise in serum amylase levels, giving rise to a misdiagnosis of acute pancreatitis. A subacute or chronic presentation, with nonspecific symptoms, is more common. Again, pancreatitis may be suspected until imaging demonstrates a dilated pancreaticobiliary afferent limb. Surgical options after Billroth II gastrectomy include conversion to a Billroth I or to a Roux-en-Y reconstruction. When the original reconstruction was with a Roux loop and the pancreaticobiliary segment is obstructed by a stenosis of the jejunojejunal anastomosis, this can simply be re-fashioned.

Efferent loop syndrome is much less common and usually occurs secondary to adhesions, internal herniation or jejunogastric intussusception. Patients present with symptoms of a proximal small bowel obstruction. Surgical intervention is indicated.

STOMAL ULCERATION

Stomal ulceration is most frequently seen after surgery for peptic ulcer disease. The ulcer occurs where the jejunum has been anastomosed to the stomach and exposed to gastric acid. A gastroenterostomy is thus prone to stomal ulceration if a vagotomy has not been performed, and a Roux loop drainage is even more vulnerable as the buffering effects of alkaline intestinal secretions at the anastomosis are absent. Therefore, a Roux loop should ideally only be used in combination with a vagotomy or when there is a small gastric remnant with less acid-producing potential. Management of recurrent and stomal ulceration is initially conservative and consists of proton-pump inhibition, eradication of *Helicobacter pylori* and avoidance of aggravating factors. If ulcers are refractory to medical management, the surgical options depend on the previous surgery. Completion vagotomy, combined with antrectomy, is often the best option.

In both stomal and recurrent ulceration, an underlying malignancy and, also, underlying pathologies such as Zollinger–Ellison syndrome, must be excluded. Ulceration associated with gastrinomas was discussed above in the section relating to peptic ulcer.

Gastrojejunocolic fistula

A gastrojejunocolic fistula is a fistula between a gastroenterostomy and the transverse colon (Figure 18.17). This was once a well-recognised complication of a long-standing stomal ulcer, but is now very rare in the developed world. Patients present with intractable diarrhoea from bacterial contamination of the small bowel, giving rise to severe nutritional deficiencies and weight loss. The situation is best managed by antrectomy, removal of the involved colonic segment followed by a gastroduodenal or gastrojejunal anastomosis and primary colonic anastomosis. In severely ill patients this may have to be a staged procedure.

A gastrocolic fistula can also occur secondary to a gastric or colonic neoplasm or as a complication of gastric surgery.

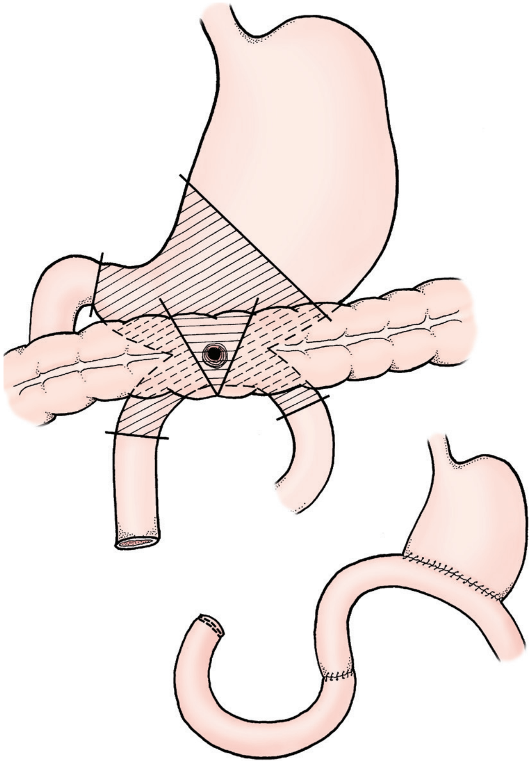

Figure 18.17 *Resection for a gastrojejunocolic fistula.*

UPPER GASTROINTESTINAL SURGERY IN INFANCY

Oesophageal atresia and tracheo-oesophageal fistula

Oesophageal atresia and tracheo-oesophageal fistula are congenital failures of development of the mid-portion of the oesophagus, and in most instances the upper oesophagus ends blindly. There are several varieties of this anomaly, but the two most common are illustrated in Figure 18.18. Failure of intrauterine swallowing by the fetus results in hydramnios and, as a result, affected infants are often born prematurely. The accumulation of unswallowed saliva should arouse further suspicion of the diagnosis, which is confirmed by the failure to pass a nasogastric tube into the stomach. Delay in diagnosis, until aspiration occurs with the first attempted feed, increases the mortality and morbidity of the subsequent surgery. In around 85 per cent of cases the atresia is associated with a tracheo-oesophageal fistula, and the two variants of the malformation are considered separately.

The surgery and perioperative care of infants with this condition are complex, and the common associated gastrointestinal, cardiac or renal anomalies must be sought as they may alter management. Transfer to a specialist centre for assessment and surgery is mandatory. Before and during transfer, a blind upper oesophageal pouch should be kept empty of secretions by repeated or continuous aspiration. Artificial ventilation may be necessary for co-existent respiratory distress, but unless the endotracheal tube can be placed sufficiently distal to occlude any fistula, increasing gaseous distension of the stomach via the fistula can compound the problems. Surgeons unable to transfer such infants are unlikely to have anaesthetic and intensive care facilities to make a neonatal thoracotomy a viable undertaking.

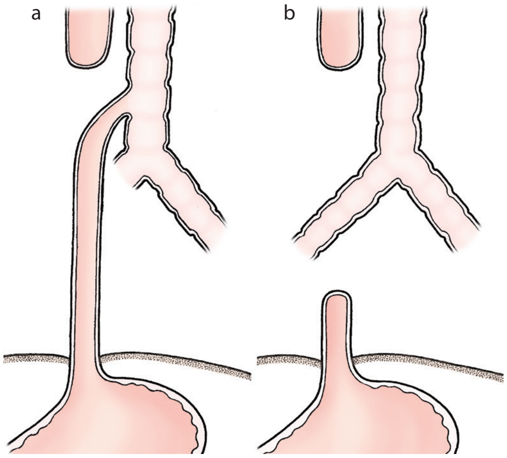

Figure 18.18 *Congenital tracheo-oesophageal anomalies. (a) Short segment atresia with a fistula to the distal oesophagus. (b) Long segment atresia without a fistula.*

OESOPHAGEAL ATRESIA WITH A FISTULA

Oesophageal atresia with a fistula is the commoner abnormality. The atretic segment is normally short, with the upper oesophagus ending blindly and close to the fistula between the trachea and the distal segment of the oesophagus (Figure 18.18a). This fistula is confirmed by the presence of gas within the stomach on X-ray. Surgical management consists of emergency repair of the fistula, combined with mobilisation of the proximal and distal oesophagus to allow a primary oesophageal anastomosis. The approach is via a right posterolateral thoracotomy through the fourth intercostal space. The pleura is swept off the chest wall and the oesophagus approached extrapleurally. The azygos vein must be divided for adequate exposure. It is sometimes not possible to approximate the oesophageal ends even after mobilisation, and further management must be similar to that described below.

OESOPHAGEAL ATRESIA WITHOUT A FISTULA

Oesophageal atresia without a fistula is confirmed by the absence of a gastric air shadow on X-ray. In many of these cases the atretic segment is of significant length and a primary anastomotic repair is not possible (Figure 18.18b). However, in the absence of a fistula the situation can be managed in the short term by gastrostomy feeding and drainage of the blind upper pouch, either by continuous suction or by the formation of a cervical oesophagostomy. The cervical approach to the oesophagus is described earlier in this chapter (p. 292) and in Chapter 10 (p. 186). Later definitive reconstruction of the oesophagus may require the creation of a gastric tube, gastric transposition or the interposition of a jejunal or colonic conduit. A colonic conduit is associated with fewer problems with reflux.

Duodenal atresia

Infants with duodenal atresia present with neonatal vomiting, which in 85 per cent of cases will be bile stained, reflecting the higher incidence of atresia distal, rather than proximal, to the ampulla of Vater. The diagnosis is confirmed by the ‘double bubble’ X-ray appearance of distension and gas restricted to the stomach and duodenum. There is a high incidence of other congenital abnormalities and a strong association with Down’s syndrome. Surgery consists of restoring intestinal continuity with a duodenoduodenostomy (Figure 18.19) or, if this is impractical, with a retrocolic duodenojejunostomy. Gastrojejunostomy should be avoided because of stasis and ulceration in the proximal duodenum. A transanastomotic feeding tube should be considered. On occasion, a duodenal diaphragm, rather than an atresia, is the only cause of the obstruction, and a duodenotomy and excision of the diaphragm may then be the more appropriate surgical manoeuvre, but great care must be taken to avoid the ampulla. A malrotation (see Chapter 23) may present neonatally with duodenal obstruction and should be considered in the differential diagnosis.

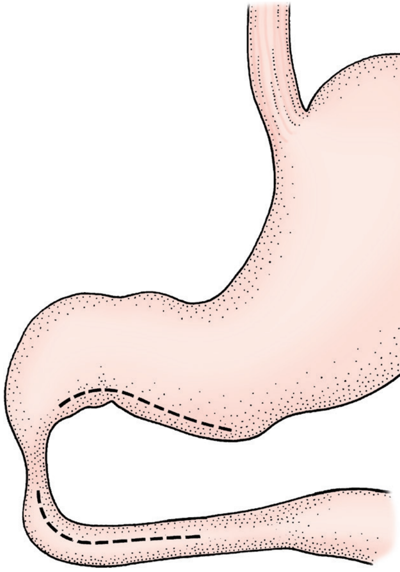

Figure 18.19 *Duodenal atresia. The incisions for a duodenoduodenostomy are marked.*

Infantile hypertrophic pyloric stenosis

Infantile hypertrophic pyloric stenosis is an acquired condition of unknown aetiology, which classically presents at about 4 weeks after birth. The infant is hungry, but persistently vomits the whole of a feed in a characteristically projectile fashion. Visible gastric peristalsis may be observed during a feed and the pyloric 'tumour' of hypertrophied muscle can be palpated after a vomit. Confirmatory diagnosis is now more often established by ultrasound examination. Treatment consists of correction of the dehydration, hypokalaemia and metabolic alkalosis, followed by surgical relief of the obstruction with a Ramstedt's pyloromyotomy. The surgery is straightforward, but many general surgeons will have to transfer these infants to regional paediatric centres for optimal anaesthetic care. Before the advent of safe general anaesthesia for these babies, the operation was frequently performed under sedation, restraint and local infiltrative anaesthesia of the abdominal wall. This may still be the safest alternative for a surgeon practising in a hospital with very limited facilities and no option of referral.

At operation, a 3- to 4-cm transverse incision is made in the right upper quadrant. This may be either a muscle-cutting or a muscle-splitting incision, but the former affords better access. The pyloric tumour is delivered into the wound, and the serosa and superficial muscle fibres of the tumour are incised in its long axis by scalpel or diathermy, as shown in Figure 18.20. The deeper fibres can be disrupted by distracting the edges of the incision, as great care must be taken to avoid breaching the mucosa, especially at the level of the duodenal fornix. Blunt forceps can be used to push the mucosa gently down and out of danger as the last fibres are divided. On completion of the operation, the intact mucosa must be seen bulging into the depths of the whole length of the incision, as inadequate release will result in persistent pyloric obstruction postoperatively. Therefore, it is also important that the releasing incision extends over the whole length of the tumour, and it must be extended proximally for 1 cm onto the gastric antrum and distally up to the prepyloric vein of Mayo at the junction with the first part of the duodenum. A mucosal breach should be sought and, if one has occurred, it is closed with an absorbable suture. Wound dehiscence is not infrequent and abdominal closure must be meticulous, using an absorbable suture material that loses tensile strength slowly.

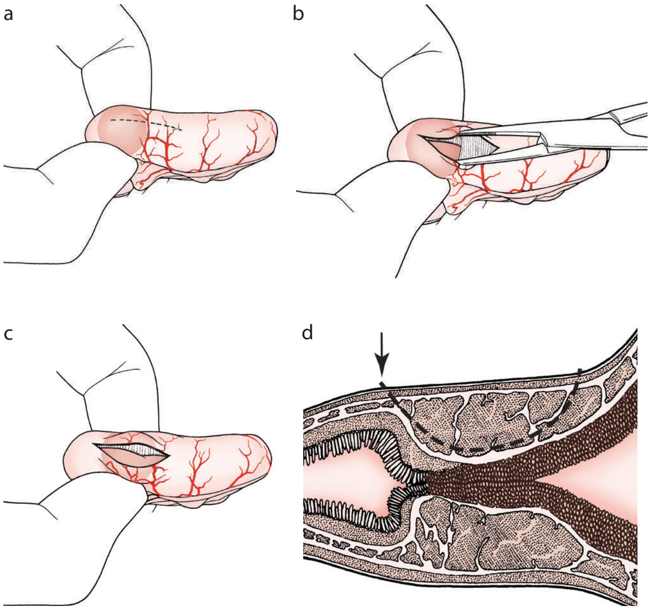

Figure 18.20 *Ramstedt's operation. (a) The posterior part of the tumour is held firmly pinched between finger and thumb. The dotted line indicates the anterior incision, which crosses very few vessels. (b) Mosquito artery forceps introduced into the incision and spread will split the deepest hypertrophied muscle fibres. (c) The pyloromyotomy is complete when intact mucosa bulges into the base of the whole incision. (d) A cross-sectional view of the tumour shows the vulnerability of the mucosa of the duodenal fornix to inadvertent penetration.*

Gastro-oesophageal reflux

Gastro-oesophageal reflux is common in infancy and early childhood, and medical management of severe cases is not always successful. Presentation is most often with vomiting, but respiratory symptoms from aspiration, dental decay from increased intraoral acidity and oesophagitis with stricture formation also occur. Severe gastro-oesophageal reflux is commonly encountered in infants with neurological impairment, where it can be a major cause of their failure to thrive. Many children who require long-term gastrostomy feeding also require anti-reflux surgery. The principles of surgery in infancy for this condition are similar to those in adults. The positions of the laparoscopic ports may, however, differ and as the soft liver is easily traumatised, a Nathanson liver retractor, introduced through an epigastric stab incision, is generally favoured. Additionally, a crural repair is normally completed before the wrap as visualisation is difficult once the wrap is in place.

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19

GALLBLADDER AND BILIARY SURGERY

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ANATOMY

The gallbladder

The gallbladder is pear-shaped and about 10 cm in length. It is attached to the inferior surface of the right lobe of the liver and is enclosed within a peritoneal sheath. The extent of this attachment varies from a gallbladder that is embedded deeply within the liver, to one that presents on a mesentery, rendering it liable to volvulus. Commonly, the lower end or fundus of the gallbladder is completely covered with peritoneum and projects slightly beyond the free margin of the liver. The body and neck are usually covered only on three sides by peritoneum, the gallbladder being attached anteriorly to the liver by loose connective tissue and easily separated from it. The neck narrows down to form the cystic duct. If a gallstone becomes lodged in the neck of the gallbladder, it creates a dilatation at this point, known as Hartmann's pouch. The cystic duct, which is of variable length and width, runs backwards and medially and joins the common hepatic duct to form the bile duct. As the bile duct is still more often known to surgeons as the common bile duct, this name is used predominantly in the text. The mucosa of the cystic duct is arranged in spiral folds, the valve of Heister. The gallbladder is supplied by the cystic artery, which is usually a branch of the right hepatic artery, though this is very variable.

The bile ducts

The right and left hepatic ducts emerge from the liver through the porta hepatis and unite to form the common hepatic duct, which is in turn joined by the cystic duct to form the common bile duct (the bile duct). The common bile duct is about 10 cm long and up to 7 mm in diameter. It runs down behind the first part of the duodenum, then either lies in a groove on the back of the head of the pancreas or tunnels through the gland substance and ends by passing obliquely through the posteromedial wall of the second part of the duodenum. The extreme lower end of the duct is accompanied by the main pancreatic duct (of Wirsung), running parallel to it and uniting with it to form the ampulla of Vater, which opens into the duodenum at the summit of a papilla. The ends of each duct and the ampulla are surrounded by circular muscle fibres, forming the sphincter of Oddi. Phasic contractions of the sphincter allow bile flow into the duodenum and possibly prevent reflux of duodenal contents into the bile and pancreatic ducts.

The hepatic ducts and the supraduodenal part of the common bile duct lie in the right free border of the lesser omentum. The hepatic artery lies medial to the common bile duct, with the portal vein posteriorly. The right hepatic artery crosses behind the common hepatic duct, before it gives off its cystic branch (Figure 19.1).

Anomalies

The above description of the anatomical relationship between the bile ducts and associated blood vessels is that given in standard textbooks of anatomy. It should be noted, however, that considerable variation may exist and those that occur most commonly are shown in Figure 19.2. A knowledge of such 'anomalies' is of great importance to the surgeon, as failure to recognise these at operation may lead to complications. The severance of an anomalous or accessory hepatic duct would lead to a bile leak and consequent biliary peritonitis, while ligation of an abnormally placed right hepatic artery might produce hepatic infarction. Other anomalies render the right hepatic duct or common bile duct liable to injury.

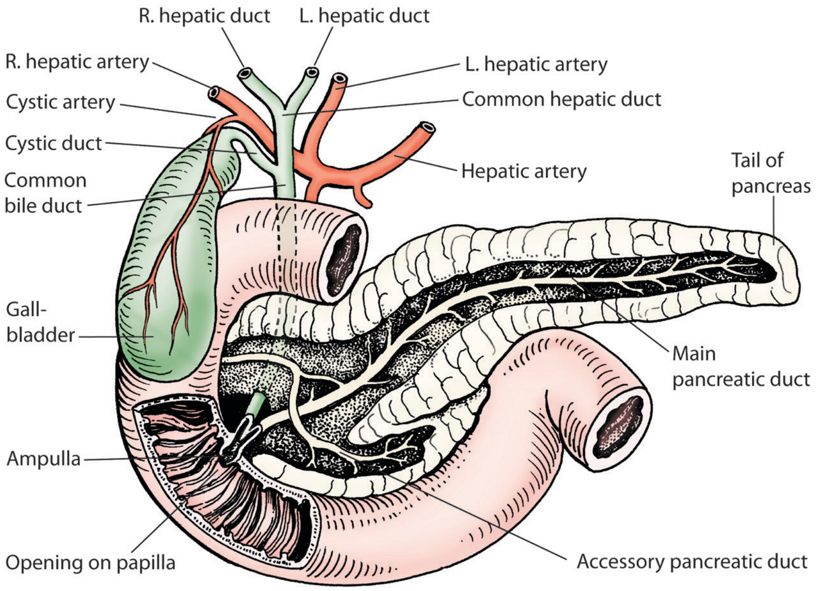
R. hepatic duct
L. hepatic duct
R. hepatic artery
L. hepatic artery
Cystic artery
Common hepatic duct
Cystic duct
Hepatic artery
Common bile duct
Tail of pancreas
Gall-bladder
Main pancreatic duct
Ampulla
Opening on papilla
Accessory pancreatic duct

Figure 19.1 *The relationship of the gallbladder and bile ducts to the duodenum and head of the pancreas.*

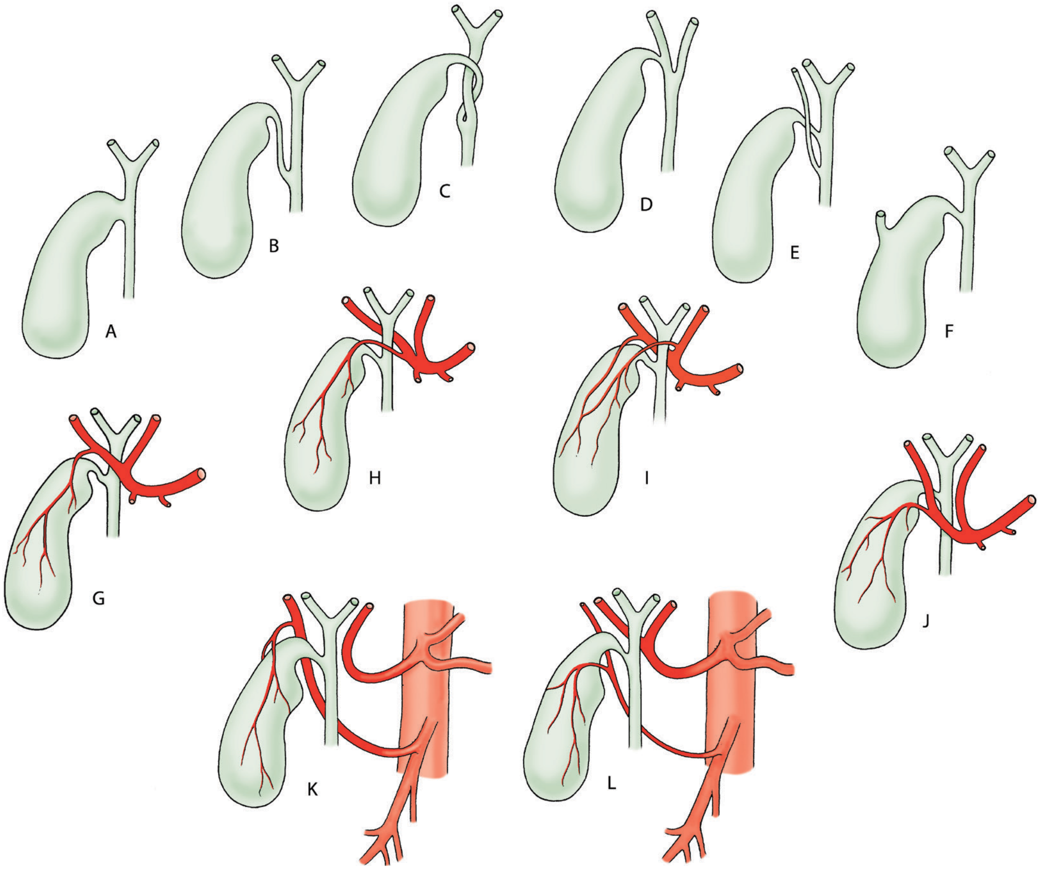
A
B
C
D
E
F
G
H
I
J
K
L

Figure 19.2 *Anomalies of the bile ducts. A = short wide cystic duct; B = long cystic duct; C = long cystic duct winding round the hepatic duct; D = cystic duct joining the right hepatic duct; E = accessory hepatic duct joining the common bile duct; F = accessory hepatic duct draining into the gallbladder; G = right hepatic artery crossing in front of the common hepatic duct; H = cystic artery arising low and crossing in front of the common hepatic duct; I = accessory cystic artery from the left hepatic artery; J = low division of the hepatic artery; K = right hepatic artery arising from the superior mesenteric artery (SMA); L = accessory right hepatic artery arising from the SMA.*

GENERAL CONSIDERATIONS IN BILIARY SURGERY

Biliary physiology

Each day, between 0.5 and 1.5 litres of bile are excreted from the ampulla of Vater, and most of the constituents are absorbed in the distal ileum. Hepatic bile is diverted into the gallbladder due to differential pressures within the biliary tree. Bile is concentrated within the gallbladder and intermittently expelled by spontaneous contractions or in response to cholecystokinin release, which occurs after eating. Cholecystokinin and glucagon allow relaxation of the sphincter of Oddi to facilitate bile flow into the duodenum.

Investigation of biliary disease

Any operation on the biliary tract should be approached with the maximum possible information, and adequate time for investigation should be allowed. Liver function tests include serum bilirubin, serum enzymes (transaminases, alkaline phosphatase) and tests of synthetic function (albumin, prothrombin time, urea). Appropriate imaging of the biliary tract may include transabdominal ultrasonography, endoscopic or laparoscopic ultrasound, endoscopic retrograde cholangiopancreatography (ERCP), percutaneous transhepatic cholangiography (PTC), radionucleotide scans, CT with vascular reconstruction, MRI and magnetic resonance cholangiopancreatography (MRCP).

Preparation for biliary surgery

The general preoperative preparation and the intraoperative and postoperative management of patients are outlined in Appendices I–III. Broad-spectrum antibiotics are recommended in emergency biliary surgery or if exploration of the common bile duct is anticipated. Subcutaneous heparin prophylaxis is indicated, except when coagulation is impaired.

ADDITIONAL PREPARATION IN THE JAUNDICED PATIENT

Both morbidity and mortality are higher following surgery in jaundiced patients, and patients must be meticulously optimised for surgery.[1]

Haemorrhage. In obstructive jaundice there is impaired absorption of fat-soluble vitamin K due to failure of bile salts to reach the intestine. This results in failure to synthesise clotting factors II, VII, IX and X and, in turn, to a coagulopathy that may manifest itself with a prolonged prothrombin time. This is corrected by administering intravenous vitamin K (10 mg per day). Occasionally, administration of blood products such as fresh-frozen plasma may be required during the perioperative period.

Infection. The majority of patients with obstructive jaundice and virtually all of those in whom the cause is gallstones have infected bile. Parenteral antibiotics (ampicillin and gentamicin, a second- or third-generation cephalosporin, or piperacillin and tazobactam [Tazocin®]) should be given on induction of anaesthesia and continued, or not, depending on the operation/operative findings.

Renal failure. Renal tubular function is compromised in jaundiced patients due to: (1) direct action of bilirubin on the tubules; (2) a degree of vascular shunting in the kidney leading to relative cortical ischaemia; (3) preoperative hypovolaemia; and (4) hypotension associated with biliary sepsis. Adequate preoperative hydration is essential to minimise the risk of acute renal failure. Preoperative volume loading with an intravenous infusion and careful monitoring of urine output in the perioperative period are essential. Patients with jaundice may also develop renal failure in the absence of clinical, laboratory or other known causes of renal failure – the *hepatorenal syndrome*. This unexplained renal failure in patients with liver disease is a clinical diagnosis of exclusion, and improvement of renal function appears to be dependent on recovery of liver function. Indeed, renal function in such patients who undergo liver transplantation returns to normal.

Biliary operations

POSITION OF THE PATIENT

The patient should be positioned supine on an operating table that allows radiographic screening for intraoperative cholangiography. Suitable laparoscopic port sites are shown in Figure 19.3, but further ports can be inserted as required to aid retraction or for the use of additional instruments.

INCISIONS FOR OPEN PROCEDURES

The surgeon has a choice of several incisions, each of which allows good access to the biliary tree:

- *Bilateral subcostal/roof-top*. This provides wide access to the upper abdomen and allows mobilisation of the liver. The use of fixed subcostal retractors (e.g. Doyen's blades) and a fixed adaptable retractor system (e.g. the Omnitract) allows constant wide exposure. This is an incision that may be suitable for a major biliary procedure.

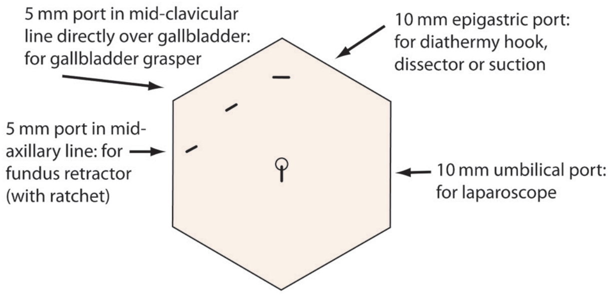
5 mm port in mid-clavicular line directly over gallbladder: for gallbladder grasper
10 mm epigastric port: for diathermy hook, dissector or suction
5 mm port in mid-axillary line: for fundus retractor (with ratchet)
10 mm umbilical port: for laparoscope

Figure 19.3 *Port sites for laparoscopic cholecystectomy.*

- *Kocher's subcostal*. This is the classic *oblique muscle-cutting* incision for an open cholecystectomy. It allows good access, especially in patients with a wide costal angle.
- *Right upper quadrant transverse*. This alternative to the Kocher incision provides a good cosmetic result.
- *Upper midline*. Some surgeons prefer to operate on the biliary tree through a midline incision while standing to the left of the patient.
- *Mayo-Robson (hockey stick)*. This is a combination of an upper midline and a medial subcostal incision.

PRELIMINARY EXPLORATION

The stomach and duodenum are examined first. The duodenum may be adherent to the gallbladder or to the porta hepatis area and it is gently retracted down and the adhesions divided. In open surgery the stomach and duodenum are then packed off, out of the operative field. Laparoscopically, more use is made of gravity by placing the patient in a steep reverse Trendelenberg with a left-down tilt to keep the other abdominal viscera out of the operative field. Aspiration of a distended stomach may improve visualisation and access. If the abdomen is open, the gallbladder is palpated for calculi, with particular attention being paid to the neck, in which a calculus may be overlooked, and the condition of the gallbladder wall is noted. In surgery for malignant disease, the entire abdomen must be carefully examined for evidence of tumour spread (nodal disease, liver metastases or peritoneal deposits).

INTRAOPERATIVE ULTRASOUND

Following preliminary exploration, intraoperative ultrasound, while being operator-dependent, can provide an invaluable aid to operative decision making in the surgery for biliary disease. The examination starts by identifying the splenoportal junction behind the neck of the pancreas, with the superior mesenteric artery running posteriorly and the pancreatic duct anteriorly. The probe is passed over the head of the pancreas and any tumour mass within is noted, measured and its relationship with the portal vein determined. The portal vein, common bile duct and hepatic artery are traced upwards in the free edge of the lesser omentum, looking for the presence of aberrant arterial anatomy. The calibre of the common bile duct is noted, as is the presence of any stones or stent within. The probe is placed over the gallbladder and the thickness of the wall and presence of stones noted. Attention is then turned to the liver. The middle hepatic vein is identified and traced into the inferior vena cava. This marks the 'principal plane' of the liver – the true division between the right and left lobes. The liver is then examined in a systematic fashion, noting the presence and extent of biliary dilatation, liver cysts and tumours.

SPECIFIC BILIARY SURGERY TECHNIQUES

Dissection

Even the simplest of biliary operations requires precise dissection in areas where there are important structures that must be preserved. Good access, illumination and assistance are all important. In the porta hepatis and in the lesser omentum, the bile ducts, the hepatic artery and its branches and the portal vein lie within the peritoneal fold. Isolation of these structures requires first the division of the overlying peritoneum with sharp dissection before the individual vessels and ducts can be cleared of fat, connective tissue and lymphatics. This clearance can be achieved by using a blunt dissection technique with, for example, a small pledget swab, but this will not be possible until the peritoneum has been divided.

Suture material

Non-absorbable material should not be used in the biliary tree as it may form a nidus for stone formation. This is particularly important when performing a biliary anastomosis, but it should also be avoided for bile duct closure or cystic duct ligation.

Anastomoses

The principles of biliary anastomoses are similar to those of other gastrointestinal anastomoses, which are discussed in more detail in Chapter 14. Interrupted absorbable sutures are suitable, but as the mucosa of the biliary tract is more adherent to the underlying muscle than that of the stomach and bowel, an extramucosal suture is not possible and sutures have to be placed full thickness.

SURGERY OF CHOLELITHIASIS

Although gallstones affect about 10 per cent of people in the Western world, more than 80 per cent of these people are asymptomatic. Cholecystectomy is not generally advocated in asymptomatic patients, but exceptions include those with sickle cell disease or hereditary spherocytosis, patients with a porcelain gallbladder (increased risk of malignancy) or those likely to be receiving long-term parenteral nutrition and who may rapidly develop sludge in their gallbladder. The commonest intervention for symptomatic cholelithiasis is removal of the gallbladder (cholecystectomy), as this is where almost all biliary calculi form. The indications and timing of cholecystectomy vary with the presentation. Gallstones that have migrated into the common bile duct, but have failed to pass on into the duodenum, should be removed either surgically or endoscopically.

The complications of cholelithiasis are numerous and include biliary colic, cholecystitis, obstructive jaundice, biliary strictures, cholangitis, pancreatitis and gallstone ileus.

BILIARY COLIC

The pain of biliary colic is due to gallbladder distension and contractions secondary to a gallstone occluding the cystic duct. The pain ceases when the gallstone drops back into the body of the gallbladder or passes into the common bile duct. There may then be a transient episode of obstructive jaundice before the stone passes spontaneously into the duodenum. Following a single episode of biliary colic, the chances of further episodes of biliary pain or complications of gallstones are high (70 per cent), and these patients should be considered for elective cholecystectomy.

ACUTE CHOLECYSTITIS

The precipitating event for acute cholecystitis is again a stone or sludge impacted in the neck of the gallbladder. If the stone does not become disimpacted (as in biliary colic), the resultant biliary stasis and gallbladder distension trigger the release of prostaglandins, which mediate an acute inflammatory response, even in the absence of concomitant bacterial infection. Cholecystectomy is indicated as recurrent attacks are likely. More than 70 per cent of patients respond to conservative management, and interval cholecystectomy can be undertaken after 6 weeks when the acute inflammatory process has settled. Alternatively, the operation can be performed when the associated oedema of early inflammation makes the tissue planes easier to dissect. With a conservative approach, some patients, such as those who develop gangrenous cholecystitis, an empyema of the gallbladder or peritonitis, will come to surgery in suboptimal circumstances. In addition, those who fail to settle and those who are readmitted to hospital with further complications of gallstones prior to their elective procedure often require surgery before all inflammation has settled. Concerns that cholecystectomy, particularly laparoscopic, was more hazardous in the acute phase appear to be unfounded and for both medical and economic reasons, cholecystectomy during the acute admission is now generally advocated.

Acute acalculous cholecystitis

Acute acalculous cholecystitis occurs mainly in patients who are already critically ill. The condition tends to be more rapidly progressive and frequently leads to gangrene of the gallbladder. Early intervention, by either cholecystostomy or cholecystectomy, is therefore indicated.

Mirizzi's syndrome

Type I Mirizzi's syndrome occurs when there is obstructive jaundice secondary to extrinsic compression of the common bile duct from a large gallstone impacted in the neck of an inflamed gallbladder or cystic duct. A type II Mirizzi's syndrome occurs when the disease progresses and there is erosion of the stone into the bile duct, creating a fistula. Conservative treatment may result in reduction of the inflammation and resolution of the jaundice, but if conservative treatment is unsuccessful, ERCP and stenting should be undertaken and surgery still delayed, as otherwise a difficult cholecystectomy must be anticipated (see below).

Cholecystostomy

Cholecystostomy is a radiological salvage procedure in a sick patient with severe acute cholecystitis. Very occasionally, an open cholecystostomy may be required if cholcystectomy is deemed unsafe in a patient undergoing open surgery. The fundus of the gallbladder is opened, gallstones and biliary sludge removed and a large Foley or other self-retaining catheter introduced into the gallbladder. A purse-string suture around the opening into the gallbladder secures the catheter, which is then brought out through the abdominal wall.

After an open or radiological cholecystostomy the tube should be left *in situ* for several weeks to allow the development of a track. A tubogram may be useful to check the biliary anatomy and the presence of residual stones. Following removal of the tube, the biliary fistula should close spontaneously within 7–10 days unless there is downstream biliary obstruction. More than 50 per cent of patients treated by cholecystostomy will be asymptomatic during the next 5 years and not every patient requires a subsequent cholecystectomy.

Laparoscopic cholecystectomy, on-table cholangiography and laparoscopic bile duct exploration

The main indication for cholecystectomy is symptomatic gallstones. Laparoscopic cholecystectomy is now the standard method where facilities and skills are available. Cholecystectomy may be performed on its own or combined with a common bile duct exploration to remove ductal calculi.

The laparoscopic procedure was first described in 1989, and since then the clinical and economic benefits have been proven, with comparable or shorter operating times, shorter hospital stay (often a day case), more rapid return to full activity and less morbidity/mortality compared with open surgery.

The indications for laparoscopic cholecystectomy are the same as for the open approach. Relative contraindications for a laparoscopic approach include extensive previous upper abdominal surgery and portal hypertension. Obesity is not a contraindication; indeed, laparoscopic surgery is more beneficial in people who are obese. Patients must be warned that there is a risk of conversion to the open procedure (approximately 2–5 per cent), which is higher in patients having an urgent cholecystectomy for acute cholecystitis (10–15 per cent).

When significant difficulties or complications are encountered in a laparoscopic cholecystectomy or bile duct exploration, conversion to an open procedure should be considered, but this decision will be influenced by the experience of the surgeon in both the open and laparoscopic techniques. Any of the difficulties encountered at a laparoscopic operation can also occur at open surgery. These difficulties are discussed in the section below on open surgery.

LAPAROSCOPIC CHOLECYSTECTOMY

Laparoscopic access is established as described in Chapter 13. This first port is normally placed at the umbilicus, but if a patient has had multiple previous operations, the peritoneal cavity may be entered in an area not associated with a previous incision. The second 10-mm port is inserted under direct vision in the midline in the epigastrium, passing just to the right of the falciform ligament, towards the gallbladder. Two 5-mm ports are introduced, one in the right mid-clavicular and one in the right anterior axillary line, angled towards the gallbladder (Figure 19.3). The positioning of the patient for optimal visualisation and the preliminary exploration are described above. After any adhesions between the gallbladder and omentum or duodenum have been divided, the gallbladder fundus is grasped and retracted towards the patient's right shoulder. A 5-mm grasper is then placed on Hartmann's pouch and, using the operator's left hand, is retracted to the patient's right, opening up the porta hepatis. The anterior and posterior peritoneum over the neck of the gallbladder is then divided with a diathermy hook and Calot's triangle carefully dissected: this is a triangle bounded by the inferior surface of the right lobe of the liver, the common hepatic duct and the cystic duct and superior border of the gallbladder (Figure 19.4). Care must be taken to stay close to the gallbladder and not to dissect close to the junction of the cystic duct and common hepatic duct, as would be done at open operation (see Figure 19.6a).

Once the cystic duct and cystic artery are clearly identified, a cholangiogram can be performed. Some surgeons perform cholangiography routinely, while others are selective, reserving it for patients with a high risk of common bile duct stones or to define the biliary anatomy. A small cut is made in the cystic duct and a cholangiogram catheter introduced. A number of methods/catheter types have been described, but a satisfactory technique is to use an infant feeding tube introduced into the peritoneal cavity via an intravenous cannula and secured in the cystic duct with a clip. It is important that the cannula is flushed through with saline or contrast prior to placement in order to eliminate air bubbles that may masquerade as stones on X-ray. Contrast is then injected while screening over the right upper quadrant. Points to note on the cholangiograms obtained are evidence of: (1) biliary tree dilatation; (2) filling defects within the biliary tree; (3) free flow of contrast into the duodenum; (4) tapering of the distal common bile duct; and (5) normal filling of the intrahepatic ducts. After satisfactory images have been obtained, the clip is removed and the catheter withdrawn. The cystic duct is clipped proximal and distal to the opening and then divided. If the cystic duct is wide, a ligature (e.g. Endoloop®) may be used to secure the cystic duct stump. The cystic artery is then clipped and divided. The gallbladder is carefully dissected off the gallbladder bed. Prior to the final disconnection, and using the gallbladder as a retractor, haemostasis of the gallbladder bed is secured and the positions of the clips placed on the cystic duct and the cystic artery are checked. The dissection is then completed and the gallbladder is retrieved through the epigastric or umbilical 10-mm port. If the gallbladder has been punctured, it should be retrieved in a bag, with every effort being made to aspirate the bile and recover any spilt stones. Drainage of the right subhepatic space with a closed-tube drainage system should be considered only in selected cases; for example, if there is significant oozing after resection of a severely inflamed gallbladder or if there is concern regarding a possible bile leak, either from the liver bed or from a cystic duct that has been difficult to secure. Any drain should be removed after 24–48 hours, provided that there is no evidence of a bile leak.

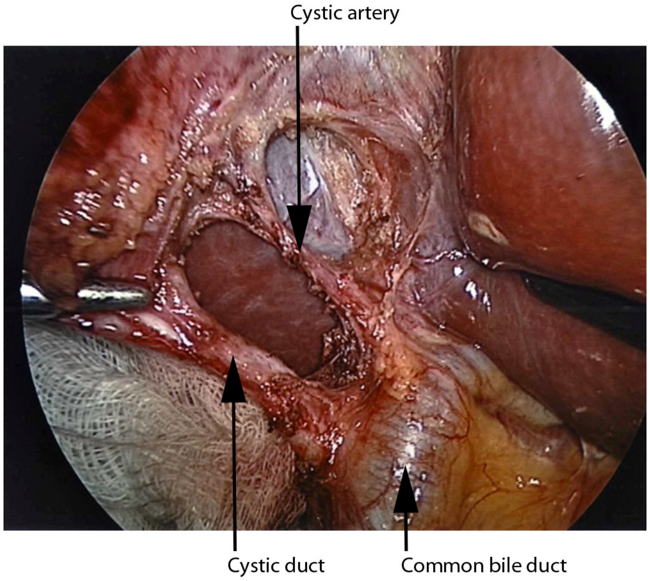

Figure 19.4 *An excellent view of Calot's triangle can be obtained at laparoscopic cholecystectomy. (Photograph by kind permission of Tim John, Basingstoke)*

LAPAROSCOPIC BILE DUCT EXPLORATION

Stones in the common bile duct can be removed either by ERCP or by operative exploration of the bile ducts. The management of patients with a high suspicion of, or proven, choledocholithiasis is dependent on local resources and expertise. One strategy is a preoperative ERCP, which may be combined with endoscopic sphincterotomy and stone extraction if stones are confirmed, followed by a laparoscopic cholecystectomy. An alternative is to proceed directly to laparoscopic cholecystectomy with intraoperative cholangiography.

If a filling defect is seen within the biliary tree on intraoperative cholangiography, the surgeon may: (1) explore the bile duct laparoscopically; (2) convert to an open procedure; or (3) perform an ERCP and stone extraction in the early postoperative period. Factors influencing this decision are the skills of the surgeon and the endoscopist, the size of the stone(s), and the diameter of the cystic duct and common bile duct. Approximately 60 per cent of patients may be explored via the transcystic route, and the stones either extracted or pushed into the duodenum using baskets or balloons (Figure 19.5). The cystic duct is then simply secured with clips or a ligature at the end of the procedure. The common bile duct may also be explored laparoscopically via a supraduodenal choledochotomy. Choledochotomy describes the making of an opening into the common bile duct to enable exploration and removal of any stones. This should only be undertaken if there is evidence of biliary dilatation and,

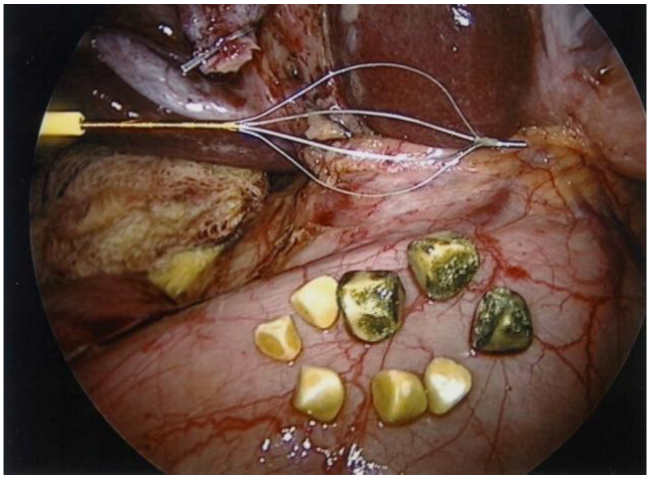

Figure 19.5 *Stones have been extracted from the common bile duct by laparoscopic transcystic instrumentation with a wire retrieval basket. (Photograph by kind permission of Tim John, Basingstoke)*

unlike at open surgery, stay sutures are not used. The choledochotomy is performed using laparoscopic scissors, taking care not to damage the posterior wall of the common bile duct. There are several techniques for exploring the biliary tree and the methodology will vary depending on the expertise and equipment available. Options include the use of a biliary Fogarty catheter or a wire retrieval basket, with either fluoroscopic image guidance or direct visualisation using a choledoscope.

A biliary Fogarty catheter is first passed up into the proximal biliary tree and advanced as far as it will go. The balloon is then inflated until slight resistance to downward traction is felt and the catheter is pulled downwards, maintaining inflation to provide slight resistance. Any calculi appearing at the choledochotomy incision are removed by forceps. The procedure is repeated for both hepatic ducts in turn until the surgeon is satisfied that the proximal biliary tree is clear. Exploration of the distal common bile duct is now undertaken. The Fogarty catheter is passed into the duodenum (judged by the distance it has passed) and the balloon inflated. The catheter is withdrawn until there is resistance, signifying that the balloon is at the sphincter of Oddi. The balloon is partially deflated while maintaining upward traction until it is felt coming through the sphincter. It is then reinflated to maintain slight resistance to traction and the catheter pulled upwards until calculi or the balloon appear at the choledochotomy incision. Calculi are removed and the procedure is repeated until the surgeon is satisfied that no calculi remain. Alternatively, if a filling defect has been identified at intraoperative cholangiography, a wire retrieval basket can be inserted via a choledochotomy, positioned using fluoroscopic control to engage an intraductal calculus, which can then be extracted under fluoroscopic surveillance. This procedure can be repeated for multiple calculi. If choledoscopy is available, a similar procedure can be undertaken using a wire retrieval basket but under direct vision rather than under fluoroscopic surveillance. When the surgeon feels that the ducts have been cleared, the common bile duct and hepatic ducts are irrigated with saline to wash out any calculus debris or blood clots. The surgeon can then inspect the bile ducts under direct vision with a choledochoscope to ensure there are no residual calculi. Alternatively, post-exploratory cholangiogram films are taken. A fine (8 Fr) Foley catheter is inserted into the choledochotomy incision and directed upwards into the proximal biliary tree. The balloon is inflated and a proximal occlusion cholangiogram obtained. The catheter is then introduced into the distal bile duct, reinflated to occlude it and a distal cholangiogram performed. Provided that the ampulla is not occluded by a stone, the pressure obtained by using this technique will allow contrast to pass into the duodenum and fully display the lower portion of the bile duct.

Following demonstration of a satisfactory clear duct system, the bile duct is usually closed primarily. The surgeon may choose to place a plastic endobiliary stent, which can be removed at subsequent ERCP. Placement of a subhepatic drain is prudent but not essential. When a bile duct has been opened but cannot be cleared laparoscopically, conversion to an open approach should be considered.

Open cholecystectomy and bile duct exploration

An open approach to a cholecystectomy may have been chosen because of the relative contraindications to a laparoscopic approach discussed above, or the surgeon may be working with financial health care restraints that preclude laparoscopic surgery. Alternatively, the operation may have started laparoscopically and conversion to an open approach chosen when difficulties were encountered. In addition, a cholecystectomy may be undertaken as part of a major resection for hepatobiliary or pancreatic pathology, including hepatic, biliary and pancreatic malignancy. Surgery for tumours of the gallbladder and bile ducts is discussed later in this chapter. All the steps of the operation must be carried out under direct vision. The patients are often obese and access difficult, so good exposure of the gallbladder is essential. Suitable incisions have been described previously, and a Kocher incision is the one most frequently used, with the surgeon standing on the patient's right.

The first step consists of freeing any inflammatory intraperitoneal adhesions between the gallbladder and adjacent viscera or omentum. Careful packing and retraction can then achieve optimal exposure. A gauze roll or pack is placed over the duodenum and this is retracted firmly downwards by the left hand of the assistant. A deep retractor is then placed under the right lobe of the liver and this is lifted gently upwards to expose the gallbladder.

There are two principal methods of removing the gallbladder: retrograde method and fundus-first method.

RETROGRADE METHOD

The generally advocated retrograde method involves early dissection and division of the cystic duct and artery, followed by retrograde dissection of the gallbladder off the liver towards the fundus. This early delineation of the key structures reduces the risk of injury to the common bile duct or right hepatic artery. When distension of the gallbladder prevents easy access to the ducts, or if there is risk of rupture, the contents should be aspirated and the puncture site closed with a stitch or clamp. Sponge-holding (Rampley's) forceps are then applied near the neck of the gallbladder and used to draw it gently forwards and to the right (Figure 19.6a). Calot's triangle is dissected by dividing the overlying peritoneum, followed by gauze stripping of the ducts to define the junction of the cystic duct and common bile duct. The cystic artery is found within Calot's triangle and ligated and divided. An absorbable ligature is then passed loosely around the cystic duct close to its junction with the common bile duct. Any stones in the cystic duct should be milked towards the gallbladder and the cystic duct clamped or ligated (Figure 19.6b) close to Hartmann's pouch. The cystic duct is then opened between the ligatures and any remaining stones removed. A bacteriology swab may be taken for culture. Intraoperative cholangiography is performed by introducing a cannula through this opening and holding it in place by tightening the ligature with a single throw. Once satisfactory evidence of a clear common bile duct has been obtained, the cannula is removed, the ligature close to the common bile duct secured and the cystic duct divided. If the cystic duct is particularly wide, it may be advisable to transfix the stump with a 2/0 Vicryl® suture.

The gallbladder is now attached by little more than the peritoneal sheath that binds it to the inferior surface of the liver. The gallbladder neck is drawn forwards away from the liver and the plane between the two dissected. As the dissection continues, the peritoneum on each side is divided with scissors or diathermy. Some haemorrhage can occur from minute blood vessels that pass directly to the gallbladder from the substance of the liver, but if the separation is carried out in the correct plane (close to the gallbladder), the bleeding is minimal. If an accessory bile duct (of Lushka) is encountered (Figure 19.2F) it should be secured and ligated. It is useful to delay the final separation of the gallbladder from the liver bed until adequate haemostasis has been achieved, as the partially separated gallbladder can provide useful retraction and aid visualisation of bleeding points.

'FUNDUS-FIRST' METHOD

This method is advised only when difficulties (particularly severe inflammatory changes) prevent the ducts from being displayed in the first steps of the operation, thus exposing them to great danger if dissection near the cystic duct and common bile duct is continued. Paradoxically, the fundus-first method also carries risks of injury, particularly to the common bile duct and right hepatic artery. Excessive traction on the mobilised gallbladder may pull these structures out of their normal alignment, rendering them liable to be clamped or included in a ligature (Figure 19.7).

Separation of the gallbladder from the liver bed is commenced at the fundus, the peritoneal sheath being divided (with scissors or diathermy) on both sides where it is reflected onto the liver. As the dissection proceeds, the gallbladder is finally attached only by the cystic artery and cystic duct. The cholangiogram is thus performed at a later stage in the dissection, when it cannot alert the surgeon to anatomical

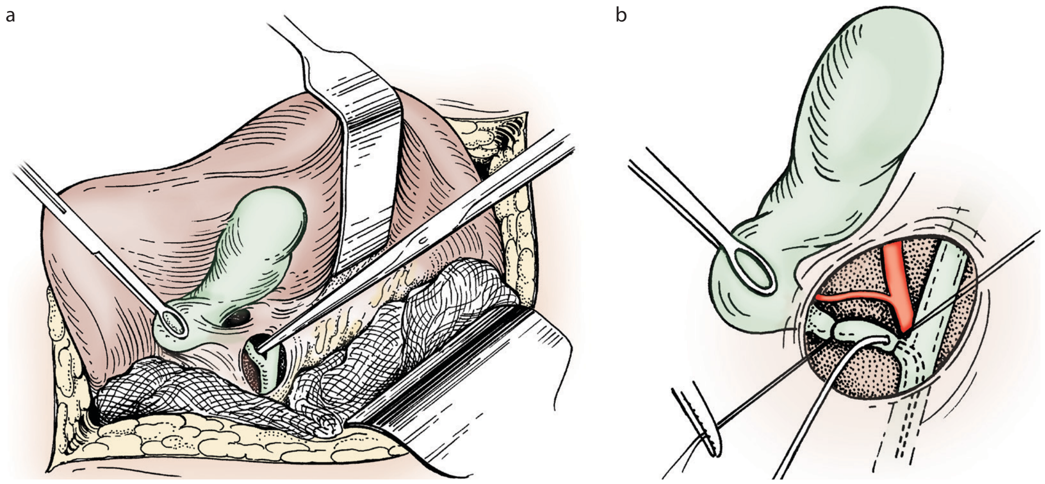

Figure 19.6 *Open cholecystectomy by the retrograde method. A longer incision in the peritoneum than illustrated here will allow better exposure of the anatomy. (a) Exposure of the cystic duct at its junction with the common hepatic duct, in the right free border of the lesser omentum. (b) The cystic duct has been ligated and a cannula inserted into the common bile duct for cholangiography. The cystic artery has been identified.*

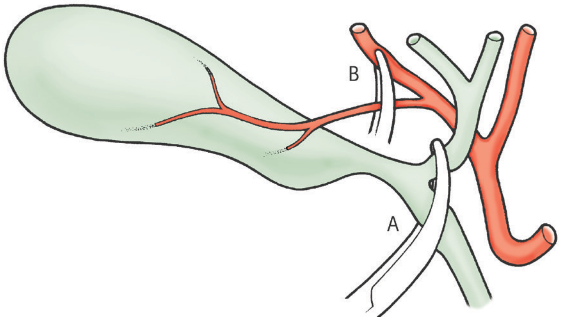

Figure 19.7 *The potential for injury to the common bile duct and right hepatic artery may be increased in the 'fundus-first' dissection, as traction on a fully mobilised gallbladder can distort the anatomy both at the termination of the cystic duct (A) and at the origin of the cystic artery (B).*

anomalies. More bleeding is encountered using this technique than using the retrograde method, where the cystic artery is controlled at an earlier stage. If, due to marked inflammation, isolation of the cystic duct and artery is thought to endanger the right hepatic artery or the common bile duct, it is better to leave part of the neck of the gallbladder *in situ* (a subtotal cholecystectomy) than to persevere with a hazardous dissection.

Drainage of the subhepatic space is unnecessary unless there are specific concerns, as discussed in the laparoscopic section above.

SUPRADUODENAL CHOLEDOCHOTOMY

When bile duct exploration cannot be undertaken via the cystic duct, the supraduodenal portion of the common bile duct, lying in the free border of the lesser omentum, is relatively accessible. In the majority of cases, exploration of the duct is for suspected calculi and the gallbladder will have been removed earlier in the operation. Kocherisation of the duodenum is no longer recommended, as the initial step as it is usually unnecessary. Kocherisation is the mobilisation of the duodenum by a lateral peritoneal incision, which opens the plane behind the duodenum and head of the pancreas so that they can be rotated anteriorly.

Operative procedure

The peritoneum over the supraduodenal portion of the common bile duct is incised and the anterior surface cleared of peritoneum and fatty tissue over a distance of 1.5 cm. One or two small vessels in the immediate supraduodenal region may require to be controlled by fine sutures. If, due to gross inflammatory changes, there is some doubt as to the actual location of the common bile duct, it may be identified by aspiration of bile with a fine-calibre needle. Stay sutures of 4/0 polydioxanone (PDS®) are inserted near the lateral borders of the duct, and a 1.5–2.0 cm longitudinal incision is made between them (Figure 19.8). A bacteriology swab is taken of the bile escaping through the incision, and the bile is then aspirated. Some floating stones may emerge with the first rush of bile, and these should be retrieved. A gentle attempt should now be made to milk any palpable stones towards the choledochotomy incision, where they may be removed using gallstone forceps.

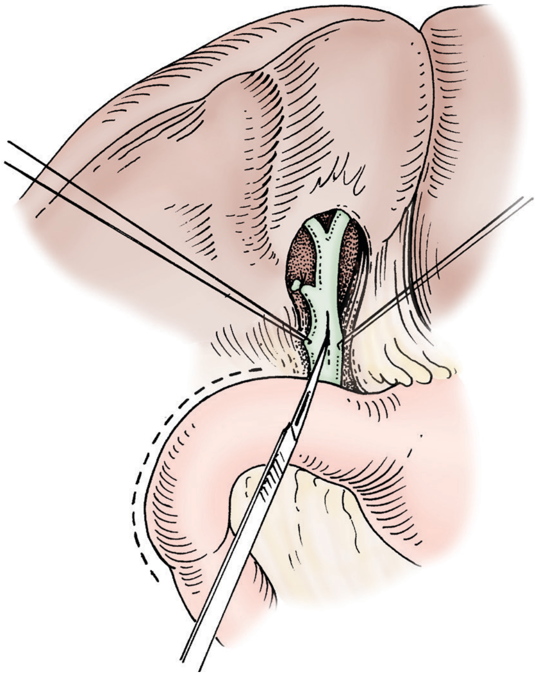

Figure 19.8 *Choledochotomy. The supraduodenal common bile duct is exposed and opened longitudinally between stay sutures. The dotted line shows the peritoneal incision for Kocherisation should this prove necessary.*

The duct is now formally explored for residual stones, palpable or otherwise. A wide variety of instruments are available for this purpose. Rigid bougies or forceps (e.g. Desjardin's or Maingot's) were traditionally used but, unless great care is exercised, damage to the duct, particularly at its lower end, may result, with subsequent stricture formation. It is therefore recommended that the initial exploration is made with a Fogarty balloon catheter as described above in the laparoscopic section. At an open exploration, confirmation that the catheter has passed into the duodenum is made by palpation of the inflated balloon. Should the Fogarty catheter fail to enter the duodenum (usually due to an impacted and palpable stone), Kocherisation of the duodenum may be helpful. Further gentle exploration with biliary forceps, using the left hand behind the pancreatic head to guide the instrument into position, will usually result in successful stone extraction. Management of impacted and apparently unmovable stones will be considered later. Confirmatory post-exploration cholangiography or choledochoscopy is then undertaken, as in the laparoscopic operation, and finally the duct closed with or without an endobiliary stent or, occasionally, over a T-tube. Most hepatobiliary surgeons in the UK no longer recommend the routine use of a T-tube if the duct has been seen to be clear on choledochoscopy or post-exploration imaging.

When a T-tube is used, a relatively fine 10- or 12-Fr guage is satisfactory. The short limbs are inserted into the common bile duct via the choledochotomy incision (Figure 19.9), which is closed using interrupted 4/0 PDS® sutures. The long limb of the T-tube is brought out to the surface through a stab incision, taking the most direct route. A small-calibre tube drain can also be placed in the subhepatic space. A T-tube cholangiogram is then taken in the postoperative period to ensure there are no retained stones. If the cholangiogram is normal, the T-tube is clamped. Removal of the T-tube will depend on the material from which it is made, as this will determine the length of time for a track to form. If it is latex rubber, the T-tube can be removed at 10–14 days, but if it is silastic it should be left for 3–4 weeks before removal. Following removal of the T-tube, there may be a small bile leak that persists for 1–2 days.

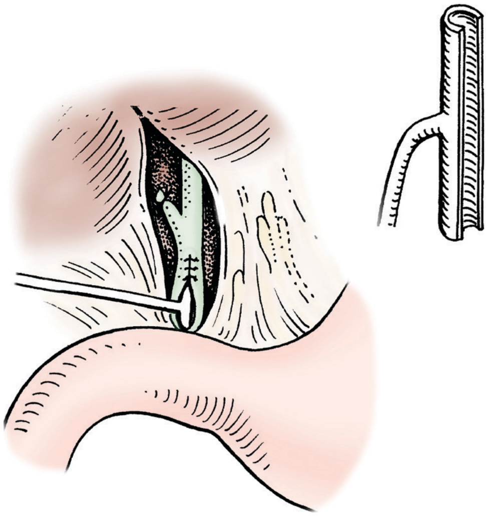

Figure 19.9 *T-tube drainage of the common bile duct. The final suture in the duct, below the T-tube, has still to be inserted.*

Difficulties and complications during cholecystectomy and exploration of the common bile duct

CYSTIC DUCT

There is sometimes difficulty in isolating the cystic duct or in following it to its confluence with the common hepatic duct. The difficulty may be caused by densely adherent planes in Calot's triangle making the anatomy impossible to elucidate. This may occur when a surgeon is forced to operate for complications of cholecystitis in a patient whose inflammation has been continuing for a week or more. The alternative strategy of cholecystostomy should be considered as a safer alternative. Difficulty can also arise when the terminal portion of the cystic duct runs a long intramural course in the wall of the common hepatic duct before entering it, or when the cystic duct winds around the common hepatic duct (see Figure 19.2C). It must be remembered that it is better to leave a portion of cystic duct *in situ* or even to perform a subtotal cholecystectomy than to persevere with a high risk of bile duct injury. Difficulty can also be due to a stone lodged in the neck of the gallbladder with intense inflammation around it. Combined pressure from the stone and the inflammation may obstruct the common hepatic duct and cause jaundice (Mirizzi type I). The stone must be released by a lateral incision to minimise any risk to the common hepatic duct, but removal of the gallbladder neck will probably be unwise. A temporary bile leak should be anticipated with a drain placed to the area. A Mirizzi type II situation will require a repair of the common bile duct or a hepaticojejunostomy reconstruction.

Simple ligation of a short wide cystic duct (see Figure 19.2A) may be insecure and it also has the potential to distort and narrow the common bile duct. A sutured closure with an absorbable suture may be a better alternative. It is sometimes impossible to pass a cholangiogram catheter through a very narrow cystic duct. It can be argued that any gallstone that was able to pass through such a duct would also have passed through into the duodenum without difficulty and that cholangiography can be abandoned. If, however, cholangiography is deemed essential, it can be performed by direct needle puncture of the common bile duct.

HAEMORRHAGE

Haemorrhage from a torn cystic artery or a slipped ligature is likely to be profuse, and injudicious attempts to stop it may result in damage to important adjacent structures. Local pressure, maintained for several minutes, against the bleeding point will usually reduce bleeding sufficiently to allow the bleeding vessel to be identified and secured when the pressure is released. Conversion to an open operation may be prudent if profuse bleeding continues. If necessary, the hepatic artery may be temporarily occluded by a soft bowel clamp placed on the free border of the lesser omentum (the Pringle manoeuvre). An injury to the right hepatic artery can also occur, and this should be considered when there is significant haemorrhage. Ligation of the right hepatic artery should be avoided and repair should be attempted. The right hepatic artery may be inadvertently ligated, being mistaken for the cystic artery, or it may be accidentally included in the ligature applied to the cystic duct (see Figure 19.7). Although one patient may suffer no consequences, in another it may prove fatal due to massive hepatic necrosis.

IATROGENIC BILE DUCT INJURIES

Most injuries to the biliary tree are iatrogenic. They are usually due to inadequate demonstration of the anatomy of Calot's triangle at cholecystectomy, and they are the most feared complication of cholecystectomy. A segment of the common bile duct may be inadvertently damaged, clipped or included in a ligature (see Figure 19.7), resulting in a major bile leak or biliary obstruction. A partial circumference injury may heal, but cause a significant stricture of the duct. Common bile duct injuries can also occur during mobilisation of the duodenum in a gastrectomy. When a surgeon suspects that a bile duct injury has occurred, it is very important not to compound the damage by making a hurried decision or an inappropriate attempt at repair. If at all possible, the help and support of a colleague who was not involved in the initial injury should be sought. Such injuries are potentially serious and should be managed by a hepatobiliary surgeon, as there is good evidence that long-term results are significantly better if the initial repair/reconstruction is undertaken by a specialist. Simple drainage of the injury and of the subhepatic space, followed by referral to a specialist unit, is often the best approach.

Immediate repair

Primary repair is very occasionally an appropriate method of repair of a partially transected bile duct. It is only practical when the injury is identified intraoperatively and if the trauma to the bile duct is minimal. It is usually advised that the anastomosis should be performed over a T-tube, brought out through a separate opening in the lower segment of the bile duct, at least 1 cm below the suture line of the repair. It must be emphasised that for such a primary repair to be successful, all the criteria for anastomotic healing must be met – that is a good blood supply, no tension, no surrounding infection and no distal obstruction. In practice, the blood supply to the damaged common bile duct is frequently compromised either because of diathermy injury or because the periductal tissues containing the feeding arteries have been stripped away. This is often the reason for late stricturing of primary end-to-end repairs. A better solution is a biliary-enteric reconstruction.

Immediate reconstruction

The common hepatic duct is excised proximally to the level of the biliary confluence, after which an anastomosis is fashioned between this and a Roux loop of jejunum (see below: Late repair or reconstruction of the bile ducts). Evidence suggests that long-term results from a primary hepaticojejunostomy are superior to those with a duct-to-duct anastomosis.

THE IMPACTED STONE AT OPEN BILE DUCT EXPLORATION

If a stone remains impacted at the lower end of the common bile duct, despite routine measures to remove it, the surgeon has a number of approaches depending on the fitness of the patient and the availability of endoscopic skills:

- To leave the stone *in situ*, drain the common bile duct by T-tube for 2–3 weeks to allow inflammation to settle, and then to perform an ERCP, sphincterotomy and endoscopic stone removal. For the very sick patient, this may be appropriate, but truly impacted stones can be very difficult to remove at ERCP and certainly stones over 15 mm are not suitable for this technique.
- To leave the stone *in situ* and perform a hepaticodochojejunostomy Roux-en-Y (see below, Late repair or reconstruction of the bile ducts).
- To remove the stone via a transduodenal sphincteroplasty. After duodenal Kocherisation, an oblique anterolateral incision is made in the second part of the duodenum. Stay sutures are then inserted in the medial wall of the duodenum on either side of the ampulla (Figure 19.10). An incision is made directly over the stone, which is then extracted. The incision in the wall of the duodenum and lower end of the bile duct is then enlarged using Pott's scissors, to a minimum length of 15 mm, and converted to a formal sphincteroplasty by approximating duodenal and bile duct mucosa using interrupted 4/0 PDS® sutures. Care must be taken to ensure apposition of mucosa at the apex of the incision. The duodenotomy incision is then closed in a single layer. Supraduodenal T-tube drainage is not normally necessary following this procedure.

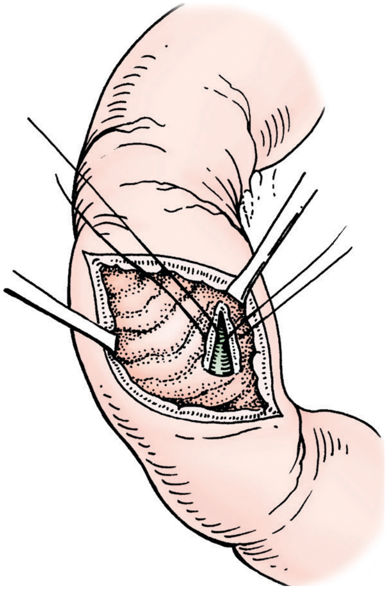

Figure 19.10 *Transduodenal sphincteroplasty.*

POSTOPERATIVE COMPLICATIONS OF BILIARY SURGERY

Retained stones

Management of retained common bile duct stones is usually with an ERCP in the postoperative period, although some small stones may pass spontaneously. This technique may not be suitable for stones retained high in the biliary tree, and may be unsuccessful if the stone is firmly impacted at the lower end. Reoperation will be required in the event of failure or non-availability of the above techniques. This is technically demanding, particularly supraduodenal re-exploration, and thus a transduodenal approach with sphincteroplasty may be preferred for stones in the distal common bile duct (Figure 19.10).

Postoperative bile leaks and biliary fistulae

A bile leak may occur into a subhepatic drain placed at the time of surgery or the bile may collect intra-abdominally and present as generalised biliary peritonitis, a localised collection or as a discharge of bile from the wound. The surgeon must have a high index of suspicion in any patient who is not well after cholecystectomy. Upper abdominal or chest pain, associated with tachycardia and persistent hypotension (the Waltman–Walters syndrome), are classical signs. An abdominal ultrasound or CT should be performed and any free fluid or collection aspirated to determine if it is bile stained. If a bile leak is confirmed, the initial management is resuscitation and the control of sepsis, combined with the drainage of bile as a controlled biliary fistula. This must be followed by approprate imaging to identify the underlying problem. It may be appropriate to ask the radiologist to place a drain into a subhepatic/subphrenic collection, but reoperation is indicated in patients with generalised biliary peritonitis.

A biliary fistula following cholecystectomy is likely to be due to a bile duct injury. Management will depend on the type of injury, the nature and location of which must be defined with MRCP, ERCP or PTC imaging. If a simple cystic duct leak is demonstrated on ERCP, insertion of a plastic endobiliary stent should allow the leak to heal. Repair of a major bile duct injury should ideally be performed either within the first week before the development of sepsis or after several months, when all sepsis has resolved. When a fistula persists after choledochotomy, it is likely that the lower part of the common bile duct is obstructed, either by a retained stone or by fibrosis, and ERCP should be performed to aid further management.

An early minor discharge of bile from a subhepatic drain placed at the time of surgery may represent a leak from a tiny undetected accessory duct that drained directly into the gallbladder. Alternatively, there may be a leak from an incompletely secured cystic duct or from the closure of a choledochotomy. Many such leaks cease spontaneously if there is no distal obstruction. However, these benign causes must not be assumed, especially if drainage is significant. Only imaging of the biliary tract can reliably exclude a bile duct injury.

Similarly, unless there is distal obstruction, a fistula that follows cholecystostomy or a T-tube choledochostomy usually closes spontaneously within 7–10 days of removal of the tube. Although a persistent fistula may close spontaneously even after a period of several months, such a policy of conservative management should not be adopted without definition of the biliary anatomy by ERCP, MRCP or PTC. If large volumes of bile are draining externally, early intervention is indicated, the nature of which will depend on the underlying conditions.

Late repair or reconstruction of the bile ducts

Late repair of a severed or stenosed duct is one of the most challenging of operations. The duct is likely to be buried in dense scar tissue and the ends may be widely retracted. The reconstruction performed depends on the level of injury, as classified by Bismuth and Majno.[2] The most successful method of reconstruction is to perform a hepaticojejunostomy, anastomosing the proximal biliary duct(s) to a Roux loop of jejunum.

HEPATICOJEJUNOSTOMY WITH A ROUX LOOP

This procedure is described here for the reconstruction of severed or stenosed ducts following iatrogenic injury, but the same technique is used for biliary reconstruction in a variety of other pathologies. It is the preferred method of surgical biliary drainage in most instances, and is the standard method of biliary reconstruction following bile duct resection.

The Roux loop is fashioned as described in Chapter 22. The jejunum is transected 25–30 cm distal to the duodenojejunal flexure, after which the closed distal end is brought up through a window in the transverse mesocolon to the right of the middle colic vessels, to be anastomosed to the proximal bile ducts, as described by Voyles and Blumgart in 1982.[3] The biliary anastomosis is performed using a single layer of interrupted 4/0 PDS® sutures. This is an end-to-side anastomosis of the common hepatic duct onto the jejunum. An incision into the side of the jejunum must be made of a size appropriate for the diameter of the transected bile duct (Figure 19.11a). The anterior layer of sutures is passed from outside to inside through the bile duct. The needles are retained and they are held for completion of these anterior sutures after the back of the anastomosis has been finished (Figure 19.11b). The anterior sutures are then elevated as retraction to expose the back wall of the duct, and the posterior sutures are all inserted, but not tied. These sutures are inserted from inside to out on the jejunum and from outside to inside on the duct. After all are in place, they are held taut and the jejunum is 'railroaded' down into place and the sutures tied (Figure 19.11c). The knots of the posterior layer are thus on the inside. The first and last sutures of the back row are held to steady the anastomosis, and all the other sutures are cut short. The front of the anastomosis is then completed using the sutures that were placed in the front of the bile duct at the beginning of the procedure. The needles are passed from inside to outside through the jejunum (Figure 19.11d). When all sutures are completed, the knots are tied (Figure 19.11e). The enteroenterostomy is then fashioned approximately 70 cm distal to this anastomosis.

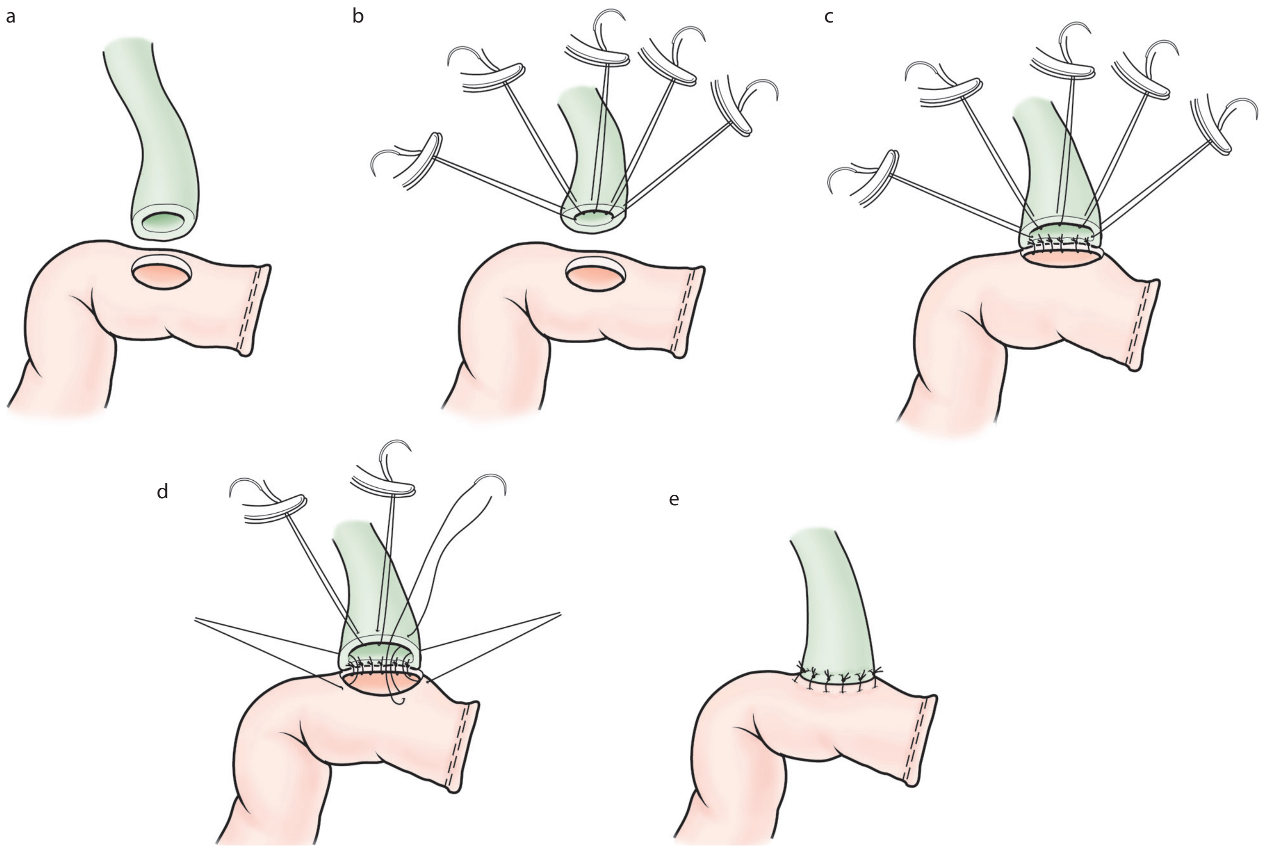

Figure 19.11 *Hepaticojejunostomy. (a) An incision is made in the Roux loop of jejunum. (b) The anterior sutures are only in the bile duct and are used to display the posterior wall of the duct while the posterior sutures are inserted. (c) The posterior sutures are tied. (d) The anterior sutures are completed. (e) The anastomosis is completed as the anterior sutures are tied.*

Sometimes, a hepaticojejunostomy cannot be performed because an injury, tumour or dense adhesion involves a considerable length of the common hepatic duct. In these circumstances, adequate biliary drainage can only be obtained by a biliary-enteric anastomosis to the left or right hepatic duct or their intrahepatic branches. Occasionally, the confluence of the hepatic ducts is high and still intact, despite an absence of extrahepatic common hepatic duct suitable for a hepaticojejunostomy. The intrahepatic common hepatic duct and the confluence within the liver are approached by the same dissection as that employed to isolate the left hepatic duct.

The left hepatic duct is usually an extrahepatic structure, accessed at the base of segment 4 of the liver by lowering the hilar plate. This involves dividing any liver tissue bridging the umbilical fissure between the base of the quadrate lobe (segment 4) and the left lobe of the liver (Figure 19.12). The liver is then elevated and an incision made at the base of segment 4, at the point where Glisson's capsule reflects onto the lesser omentum. The dissection into the liver is then deepened in this plane from left to right, exposing the structures of the left portal triad. The position of the left duct is confirmed by needle aspiration. The duct is opened lengthwise with a scalpel and the incision is extended using Pott's scissors. If the confluence is intact, both the left and right lobes of the liver can be drained by this approach.

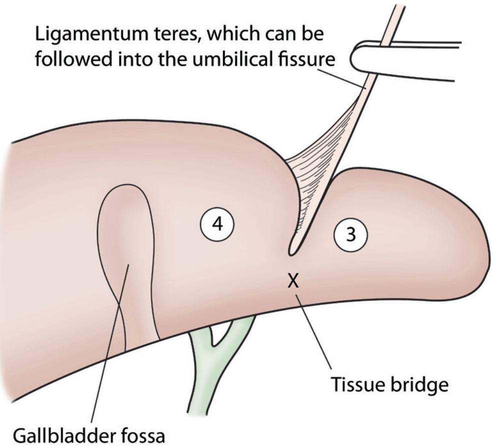
Ligamentum teres, which can be followed into the umbilical fissure
4
3
X
Tissue bridge
Gallbladder fossa

Figure 19.12 *Access to the right and left hepatic ducts may be necessary when there is no suitable extrahepatic common hepatic duct for a hepaticojejunostomy. The tissue bridge between segments 3 and 4 is divided to expose the left portal triad. The right hepatic duct can be approached from the gallbladder fossa.*

If there is complete separation of the left and right ducts, the right lobe of the liver must be drained by a separate approach to the right duct through the base of the gallbladder fossa. If the left duct is obliterated (e.g. by fibrosis or tumour), a biliary-enteric anastomosis can be performed onto the duct of segment 3, which runs in a relatively constant position to the left of the umbilical fissure and is accessed by dividing the liver on its anterior surface just to the left of the base of the falciform ligament. Intraoperative ultrasound may be a useful adjunct to help identify the duct (see also Chapter 21).

SURGERY OF OBSTRUCTIVE JAUNDICE AND BILIARY STRICTURES

A complete obstruction of the biliary tree results in progressive obstructive jaundice. This obstruction can be due to a stone impacted in the lower end of the common bile duct. However, steadily deepening obstructive jaundice, without preceding biliary colic, suggests obstruction of the duct by malignant disease, a benign biliary stricture or chronic pancreatitis. Malignant disease may be a primary tumour in the head of the pancreas, bile ducts, gallbladder or ampulla of Vater, or may be secondary to enlarged metastatic lymph nodes in the porta hepatis. Benign biliary strictures may be caused by primary or secondary sclerosing cholangitis, parasitic infections (*Ascaris*, *Clonorchis*, *Echinococcus*), traumatic injury (often post cholecystectomy) or idiopathic inflammatory strictures. Non-malignant strictures often cause incomplete obstruction, and the morbidity is related to secondary biliary cirrhosis, sepsis and stone formation.

ACUTE CHOLANGITIS

Patients with complete or partial extrahepatic biliary tract obstruction can become severely unwell with acute cholangitis, the classic symptoms and signs of which are right upper quadrant pain, jaundice and rigors (Charcot's triad). Acute (or ascending) cholangitis is due to secondary bacterial colonisation of stagnant bile and subsequent bacteraemia. This is a surgical emergency and patients must be resuscitated with fluids, oxygen, intravenous antibiotics and analgesia, followed by urgent decompression of the biliary tree by endoscopic, percutaneous or surgical means.

Biliary strictures

The surgical management of a biliary stricture is dependent upon its aetiology and its anatomy.

POST-TRAUMATIC STRICTURES

Most post-traumatic strictures are secondary to iatrogenic bile duct injuries sustained during gallbladder surgery. Their management has been discussed above.

INFLAMMATORY STRICTURES OF THE BILIARY TREE

Inflammatory strictures of the biliary tree may result from injury or from fibrosis following inflammation (for example, secondary to an impacted common bile duct stone). When stenosis involves only the orifice of the duct, it may be dealt with either by transduodenal sphincteroplasty (see above) or by endoscopic sphincterotomy. When the stricture is thought to be too high or too long to be treated by simple incision of the duct orifice, a hepaticojejunostomy with a Roux loop of jejunum should be performed, as described above.

Ascaris worms can enter the biliary tract through the duodenal ampulla, where they cause intermittent partial obstruction, irritation and infection. The extensive inflammatory biliary strictures associated with parasitic infestation of the biliary tree are often complicated by additional involvement of the intrahepatic bile ducts. Some patients with severe disease eventually require replacement of their extrahepatic ducts with a Roux loop hepaticojejunostomy. Occasionally, bypass may have to be on to a dilated intrahepatic duct above a stricture. Complications of intrahepatic strictures and calculi will continue even after excision of the extrahepatic ducts and reconstruction with a hepaticojejunostomy. In these patients, the addition of an access loop for radiological or endoscopic dilatation of recurrent intrahepatic biliary strictures and the retrieval of further biliary stones is desirable.[4] Subsequent percutaneous access to a subparietal hepaticojejunal access loop can be facilitated by marking its position with Ligaclips® or wire for radiological identification(Figure 19.13a). A gastric access loop allows easy endoscopic access[5] and may be of particular value when endoscopic skills are available but interventional radiological facilities are less well-developed (Figure 19.13b).

PRIMARY SCLEROSING CHOLANGITIS

Primary sclerosing cholangitis (PSC) is a chronic cholestatic syndrome characterised by diffuse fibrosing inflammation of the intra- and extrahepatic bile ducts. It is likely to have an autoimmune aetiology and is associated with ulcerative colitis in about 70 per cent of cases. PSC is progressive, leading to biliary cirrhosis, portal hypertension and death from liver failure. No effective medical treatment is available. While a dominant extrahepatic biliary stricture may be treated by hepaticojejunostomy, liver transplantation is the only definitive treatment offering long-term survival for patients with end-stage PSC.

MALIGNANT STRICTURES

A minority of malignant strictures are amenable to potentially curative resection followed by reconstruction of the biliary tree. The radical surgery of cholangiocarcinoma is described below, while that of pancreatic, bile duct and duodenal tumours in the periampullary region is covered in Chapter 20. Palliative relief of the biliary obstruction is often the only useful intervention for the majority of these malignant strictures.

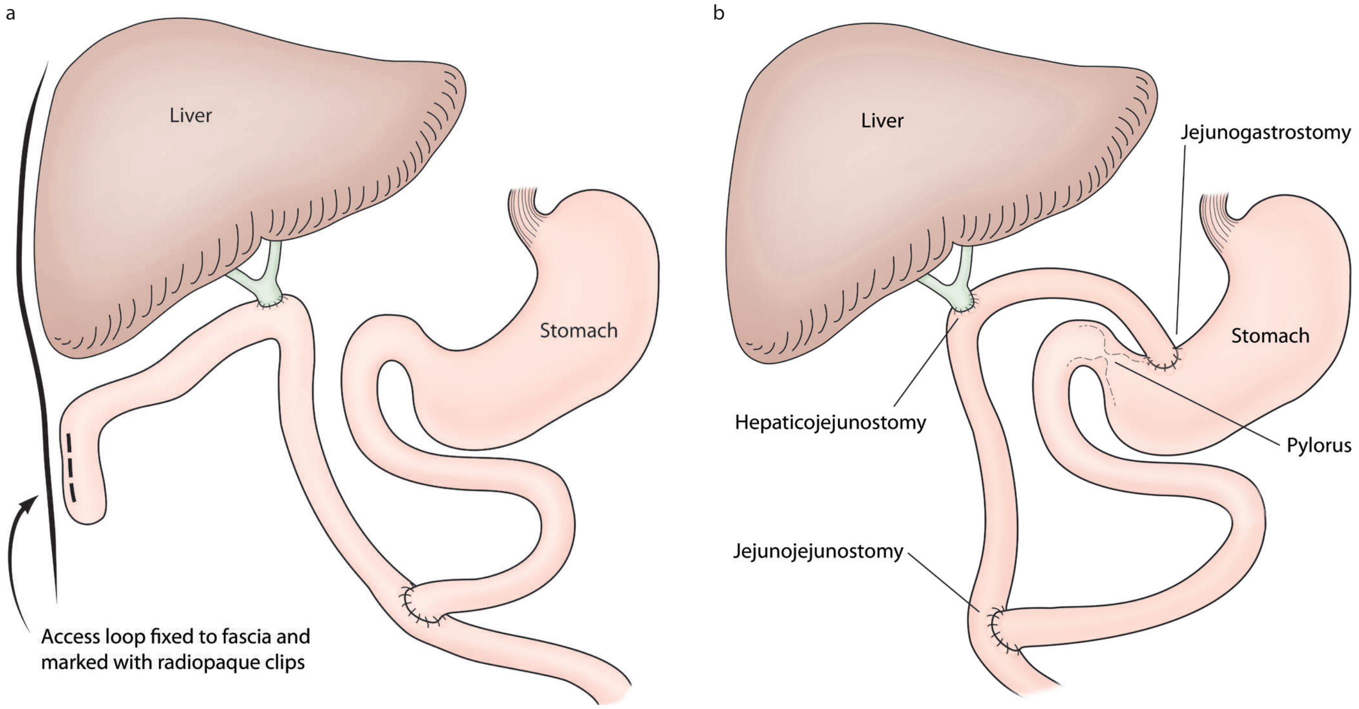

Figure 19.13 *Hepatic access loops. (a) A subparietal access loop, which is easily entered radiologically. (b) A gastric access loop, which can be entered at endoscopy.*

Palliative relief of biliary obstruction

Patients with malignant biliary stricture can now be staged accurately prior to surgery. Life expectancy is generally short when the disease is no longer amenable to a potentially curative resection. While palliative resection is seldom beneficial, relief of the obstructive jaundice offers good short-term relief of symptoms. Endoscopic stenting has virtually replaced the operations for biliary bypass in these circumstances, and has the advantage that a laparotomy can be avoided during the last few months of life.

SURGICAL BYPASS

An anastomosis of the gallbladder or supraduodenal common bile duct to the gastrointestinal tract can be fashioned to form an alternative channel for the drainage of bile in cases of irredeemable obstruction of the common bile duct, such as that caused by a periampullary carcinoma or by chronic pancreatitis.

Cholecystojejunostomy was once the standard bypass for inoperable carcinoma of the head of the pancreas that presented with obstructive jaundice. The first loop of jejunum was brought up to the fundus of the gallbladder. An incision was made in each and a side-to-side anastomosis constructed.

Choledochoduodenostomy was often preferred in benign disease. The supraduodenal common bile duct was anastomosed to the duodenum.

However, these operations have a very limited role in the management of biliary obstruction in the current era, with advances in biliary stenting techniques by either the percutaneous transhepatic or the endoscopic route. When stenting is impractical or a longer-term solution is required, a hepaticojejunostomy Roux-en-Y is now considered to be the optimal type of biliary drainage operation. However, hepaticojejunostomy is a major procedure and the simpler bypass operations may still have a palliative role for surgeons working in areas without access to endoscopic or transhepatic stenting.

TUMOURS OF THE BILE DUCTS

Benign tumours of the bile ducts are very uncommon and include epithelial (adenoma, cystadenoma) and non-epithelial (neurofibroma, lymphangioma, haemangioma) lesions. Management of the majority of lesions is by surgical excision and biliary reconstruction (usually hepaticojejunostomy) to relieve the biliary obstruction and/or exclude malignancy.

Cholangiocarcinoma

The incidence and recognition of cholangiocarcinoma are increasing. It is associated with conditions causing chronic inflammation, such as PSC, parasitic infections (*Clonorchis sinensis*) and Caroli's disease, or with occupational exposure to carcinogens such as aflatoxin or vinyl chloride.

Cholangiocarcinomas are often associated with a dense desmoplastic reaction in the surrounding biliary epithelium and they exhibit submucosal spread or perineural invasion. Their extent is thus difficult to assess macroscopically. Patients with cholangiocarcinoma usually present after the sixth decade of life with progressive jaundice and weight loss. CT, MRI, cholangiography and mesenteric angiography may all be used to assess resectability. A preoperative tissue diagnosis may be obtained from biliary brushings or bile cytology.

Unfortunately, the majority of patients are suitable for palliation only in view of the extent of disease and co-morbidity. However, resection with curative intent may be possible in selected patients.[6] Median survival following a 'curative' resection is of the order of 24 months, compared with 5 months for irresectable disease. Features that suggest an irresectable tumour include involvement of the main portal vein or common hepatic artery, involvement of segmental vessels or ducts on opposite sides of the liver, bilateral involvement of second-order intrahepatic ducts, multifocal disease on cholangiography and liver atrophy inconsistent with a viable liver remnant after resection.

Depending on the location of the tumour, resection may involve only a radical bile duct excision or it may have to be combined with a pancreaticoduodenectomy or partial hepatectomy. For tumours below the hepatic confluence, the peritoneum of the lesser omentum is divided immediately above the duodenum and the common bile duct ligated and divided. The common bile duct is freed from the underlying structures and, as it is dissected cranially, the gallbladder is mobilised from its bed and included in the excised specimen. Hilar tumours require excision of the confluence of the right and left hepatic ducts combined with a hemihepatectomy (see Chapter 21).

Palliation includes relief of jaundice, usually by biliary stenting, control of infection and nutritional and psychological support. There is some evidence that palliative chemotherapy with newer agents such as gemcitabine may improve survival and quality of life, but this is still under evaluation in the context of clinical trials.

CARCINOMA OF THE GALLBLADDER

Although gallbladder cancer is rare, it is the commonest form of biliary tract malignancy. The disease is found in 1–2 per cent of cholecystectomy specimens and is commonest in elderly women. Risk factors for malignancy include gallbladder polyps greater than 1 cm in diameter, a porcelain gallbladder (due to intramural calcification) and an anomalous pancreaticobiliary duct junction. While 70 per cent of patients have gallstones, this association has never been proven to be causative. Some 80 per cent of cases are adenocarcinoma, the remainder being squamous or adenosquamous carcinomas.

Patients may present in one of three ways: (1) with features of suspected or confirmed biliary malignancy (pain, jaundice and weight loss); (2) as an incidental finding at the time of cholecystectomy for presumed benign disease; or (3) as an incidental finding on pathological examination of a resected gallbladder. Cholangiography and CT are the mainstays of disease staging. Treatment of gallbladder cancer depends on disease stage and the mode of presentation.[7] Once cancer of the gallbladder has invaded the hilar ducts and caused obstructive jaundice, it is rarely resectable for cure. If a tumour is discovered at laparoscopic cholecystectomy, a formal open operative assessment of resectability should be made. If the disease is localised, a cholecystectomy combined with wedge resection of the gallbladder bed or resection of segments 4 and 5 may be considered. Most authors would advocate reoperation with radical bile duct excision and resection of the gallbladder bed if malignancy (other than a T1 tumour) is discovered incidentally on pathological examination of the specimen. However, the published experience is too small to prove additional survival benefit with this approach. There is no clear evidence base for adjuvant chemotherapy or radiotherapy, but this may be offered to patients with a good performance status. The overall 5-year survival is less than 5 per cent.

CONGENITAL ABNORMALITIES OF THE BILIARY TREE

Biliary atresia

Biliary atresia is a neonatal obstructive cholangiopathy of unknown aetiology characterised by a fibrosclerosing obliteration of the extrahepatic bile ducts. It has been classified by the Japanese Society of Paediatric Surgeons into three types. In type 1 there is a common hepatic duct remnant and in type 2, although no common hepatic duct, there is a left and right duct remnant. In type 3, the commonest type, occurring in 88 per cent of cases, there is atresia of the whole of the extrahepatic ductal system.

Diagnosis

A diagnosis of biliary atresia should be considered in a neonate with conjugated hyperbilirubinaemia. Investigation is urgent, as surgery before 8 weeks of age gives the best chance of good bile flow and long-term survival. Other causes of jaundice must be excluded, and confirmatory investigations include bile duct imaging and technetium-labelled hepatobiliary excretion scans. Currently, the most reliable test for distinguishing biliary atresia from idiopathic neonatal hepatatis, aside from exploratory laparotomy, remains a percutaneous liver biopsy assessed and reported by an experienced pathologist.

Treatment and outcome

The initial treatment is surgical reconstruction of the biliary tree. At laparotomy, a shrunken fibrotic gallbladder suggests atresia and precludes operative cholangiography. If the gallbladder is patent, it is aspirated. If bile is obtained, this suggests either a type 1 atresia or a hepatitis syndrome, and a cholangiogram should be performed. If type 1 disease is confirmed, a hepaticojejunostomy is undertaken. Types 2 and 3 disease are treated by the portoenterostomy procedure described in 1959 by Kasai and Susuki,[8] who observed bile drainage from microscopic ductules in the porta hepatis after excision of the fibrosed hepatic ducts. Consequently, they developed a procedure whereby the atretic extrahepatic tissue is removed and a Roux-en-Y jejunal loop is anastomosed to the hepatic hilum.

Long-term outcome in these infants depends on the occurrence of ascending cholangitis, portal hypertension and the progress of intrahepatic inflammation. Age at operation and surgical experience are both critical prognostic factors. Short-term success, with restoration of bile flow and normalisation of bilirubin, may result in a 10-year survival of up to 90 per cent with a native liver. If portoenterostomy fails, death before the age of 2 years is likely without liver transplantation. Yet even with early surgery, most patients (70–80 per cent) eventually develop end-stage biliary cirrhosis and require liver transplantation.[9] Biliary atresia is the most frequent cause of chronic end-stage liver disease in children, and is the leading indication for liver transplantation in the paediatric population, accounting for 40–50 per cent of all paediatric liver transplants.

Choledochal cysts

Choledochal cysts are not an isolated entity, but rather a spectrum of abnormalities in the pancreatohepatobiliary system. Choledochal cysts are more common in females and have a high incidence in Japan and Asia. Their aetiology is unknown, but an abnormal pancreaticobiliary duct junction and the formation of a common channel are found in a high proportion of patients. It is speculated that this results in reflux of pancreatic enzymes into the biliary tree, causing inflammation, dilatation and fibrosis.

Classification

Choledochal cysts were classified in 1977 by Todani *et al.*[10] into five types (Figure 19.14). The most common is the type I cyst, a solitary fusiform dilatation of the common bile duct into which the cystic duct enters; type II is a supraduodenal common bile duct diverticulum; type III is a choledochocoele in the distal common bile duct; type IV is the second most common, with extra- and intrahepatic cysts; and type V is confined to the intrahepatic ducts and may merge into the syndrome of Caroli's disease, which in turn is associated with congenital hepatic fibrosis.

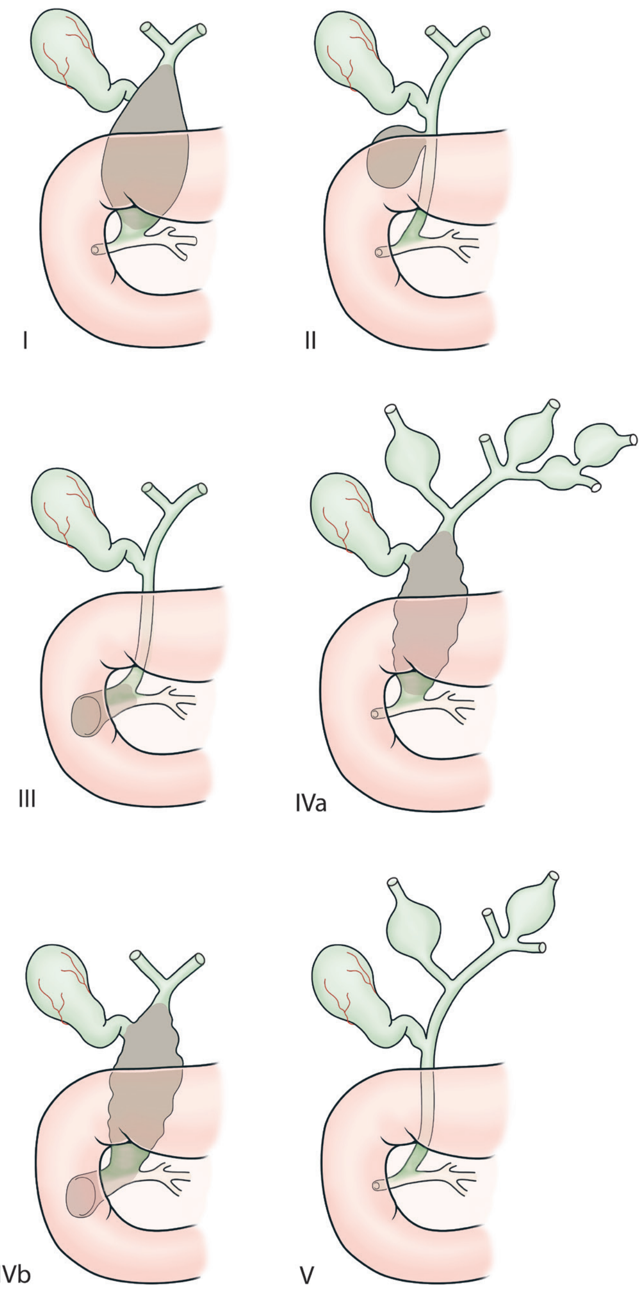

Figure 19.14 *Modified Todani classification of choledochal cysts.*

Presentation and treatment

Choledochal cysts may present in older infants and young children or remain asymptomatic for many years. Clinical features include recurrent abdominal pain, jaundice, a right hypochondrial mass, recurrent cholangitis and pancreatitis. Emergency presentation with cyst rupture is a recognised complication in older infants. If choledochal cysts are left untreated, liver abscesses, cirrhosis, portal hypertension and malignant change can result.[11] The diagnosis is usually made by ultrasound, but definition of the anatomy of the biliary tree using ERCP, PTC or MRCP is essential. Treatment is surgical, based on cyst type and associated hepatobiliary pathology. In principle, the extrahepatic biliary tree should be excised and bile flow re-established by a biliary-enteric anastomosis. For type IV intrahepatic cysts, liver resection may be necessary and patients with Caroli's disease (type V) may require liver transplantation (see also Chapter 21).

Cystenterostomy is contraindicated. Long-term complications will still develop, and patients who have had a bypass still require definitive surgery. This will be more difficult and has a lower chance of success if a previous cystenterostomy has been performed. Occasionally, a temporary solution is required in an emergency for a patient who is unfit for a major procedure or the necessary surgical skills are unavailable. Temporary T-tube drainage of the cyst is preferable in these circumstances to any anastomosis of the cyst onto the bowel.

FUNCTIONAL DISORDERS OF THE BILIARY TREE

Functional disorders causing pain of biliary origin in the absence of gallstones or other biliary organic disease may be attributed to gallbladder dyskinesia or sphincter of Oddi dysfunction. Gallbladder dyskinesia may be diagnosed using radionucleotide scanning to demonstrate incomplete gallbladder emptying following a cholecystokinin stimulus. Cholecystectomy is usually curative. Patients with sphincter of Oddi dysfunction include those with spasm or dyskinesia. This dysfunction is diagnosed using biliary manometry, which may show a raised basal sphincter pressure, abnormalities in the direction and frequency of contractions or a paradoxical response to a cholecystokinin stimulus. Treatment involves division of the sphincter, either endoscopically or by a transduodenal operation. The open, transduodenal approach may include sphincterotomy and sphincteroplasty (as previously described) or septectomy. This latter, more radical, operation includes ablation of the high-pressure zone at outlets of both the pancreatic and bile ducts.

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20

SURGERY OF THE PANCREAS, SPLEEN AND ADRENAL GLANDS

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THE PANCREAS: ANATOMY, EMBRYOLOGY AND PHYSIOLOGY

Anatomy

The internal anatomy of the pancreas and its relationship to the duodenum and bile ducts is illustrated in Figure 19.1 (p. 322). The pancreas consists of a head, uncinate process, neck, body and tail. The head and uncinate process are located within, and are intimately associated with, the concavity of the duodenum. The body and tail pass upwards and backwards covered with the peritoneum of the posterior wall of the lesser sac, with the tail terminating at the splenic hilum. The anterior surface of the pancreas is for the most part in contact, through the lesser sac, with the posterior aspect of the stomach. The posterior surface of the pancreas is associated with the inferior vena cava, aorta, portal vein, splenic vein, the left renal vessels and the left kidney. The portal vein is formed by the confluence of the superior mesenteric vein and splenic vein behind the neck of the pancreas. The splenic artery has a wavy course along the upper border and the splenic vein lies behind the body and tail of the pancreas. The superior mesenteric artery and vein pass over the anterior aspect of the uncinate process and lie posterior to the neck of the pancreas. The neck of the pancreas lies in front of the vertebral bodies and is at risk of damage during compression-type injuries to the abdomen. An accessory or 'replaced' right hepatic artery arising from the superior mesenteric artery may run upwards behind the head of the pancreas.

Blood supply

Most of the blood supply to the pancreas is derived from the coeliac axis through the splenic and superior pancreaticoduodenal arteries. The inferior half of the head of the pancreas and the uncinate process are supplied by the superior mesenteric artery through the inferior pancreaticoduodenal artery. The superior and inferior pancreaticoduodenal arteries anastomose to form an arcade around the head of the pancreas. This is an important collateral channel; the sole arterial blood supply to the liver may be through this channel in occlusive disease of the coeliac axis.

The venous drainage of the pancreas is via the portal system, and the lymphatic drainage follows the arterial supply.

Nerve supply

The pancreas receives parasympathetic innervation from the vagus nerve and sympathetic innervation, including pain sensation, through the greater splanchnic nerves (T6–T10).

Embryology

The pancreas is formed from two outpouchings of the developing intestinal tract termed the dorsal and ventral pancreatic buds. The superior part of the pancreatic head, the body and the tail of the pancreas all develop from the dorsal pancreatic bud. The dorsal pancreatic duct forms the main pancreatic duct and initially drains at the site of the minor duodenal papilla. The inferior half of the pancreatic head and the uncinate process develop from the ventral pancreatic bud. This arises in common with the bile duct at the site of the major duodenal papilla (which marks the junction between the fore and mid-gut). The ventral pancreatic bud rotates posteriorly to fuse with the dorsal pancreatic bud. Following fusion of the ventral and dorsal buds, there is reorganisation of the two pancreatic ductal systems, with the result that the dorsal (main pancreatic) duct drains mainly through the major duodenal papilla. Fusion of the two pancreatic ductal systems fails to occur in 5–10 per cent of individuals, giving rise to pancreas divisum in which the main pancreatic duct drains through the minor duodenal papilla, situated 2–3 cm above the major duodenal papilla. Pancreas divisum is a relatively common anomaly of which the pancreatic surgeon must be aware (Figure 20.1). The consequences of pancreas divisum remain contested, although it is believed that it may give rise to main pancreatic duct hypertension resulting in recurrent episodes of abdominal pain and acute pancreatitis.

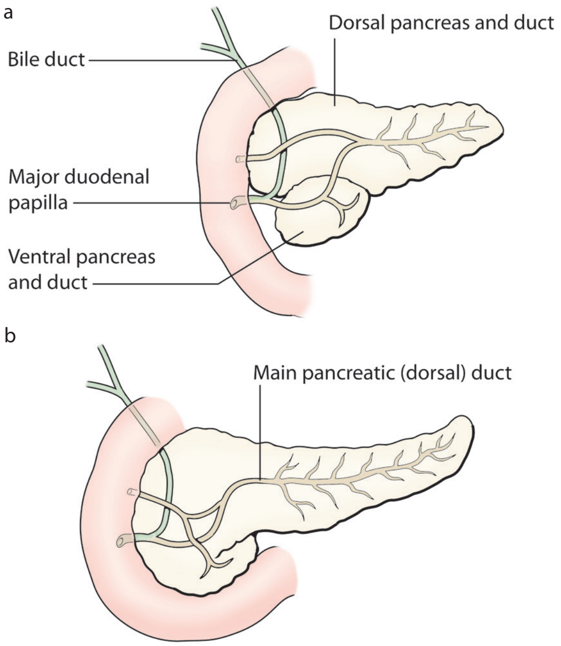

Figure 20.1 *Pancreatic ducts. (a) Developmentally, the pancreas consists of a separate dorsal and ventral organ, each with its own duct. The larger dorsal pancreatic duct opens into the duodenum above the opening of the bile duct. In pancreas divisum there is a failure of communication between the two ductal systems and this anatomical arrangement persists. (b) Fusion of the two parts of the pancreas and reorganisation of the ducts results in the normal adult anatomy. The main dorsal pancreatic duct now drains through the major duodenal papilla.*

Histology

The pancreas is a composite gland with both exocrine and endocrine components. The exocrine component forms the bulk of the gland, with the serous acinar cells comprising 80 per cent of the gland volume. In contrast, the endocrine component within the islets of Langerhans comprises a mere 2 per cent of the gland structure. The remaining 18 per cent is comprised of ducts, nerves, vessels and connective tissue.

Pancreatic physiology

The surgeon must remember that the pancreas has both exocrine and endocrine function. Exocrine secretion of digestive enzymes (amylase, proteases, lipase, nuclease) is from pancreatic acinar cells, which form the bulk of the gland. Bicarbonate-rich fluid, also important for digestion, is secreted by centroacinar and ductal cells. Pancreatic enzyme secretion is stimulated by a number of hormones, although the predominant influence is that of cholecystokinin, which is secreted in response to fat and amino acids within the duodenum. Centroacinar cell secretion is controlled by the hormone secretin, released in response to acid within the duodenum.

The endocrine component within the islets of Langerhans includes the α cells, which secrete glucagon, the β cells, which secrete insulin in response to a rise in blood glucose, and the δ cells, which secrete somatostatin.

GENERAL PANCREATIC SURGICAL TECHNIQUE

Pancreatic surgery is highly specialised and patients should, if at all possible, be transferred to a specialist pancreatic unit. This is possible in many cases of pancreatic trauma, the management of which was discussed in Chapter 15 (p. 252). However, the general surgeon with a different subspecialty interest must still understand the challenges posed by the pancreas. Unwelcome encounters with the pancreas can arise in a number of operations, and all experienced surgeons have a healthy respect for an organ that has a justifiable reputation for being extremely unforgiving of surgical encroachment. Injury to the pancreas can occur during any dissection in its vicinity, and care must be taken to avoid damage during gastric, colonic, aortic, splenic and adrenal gland surgery.

Identification

The edge of the pancreas is usually fairly easy to distinguish from the surrounding extraperitoneal fat in ideal operating conditions, as it is slightly pinker and usually a little firmer. However, the surgeon must be aware of the proximity of the gland, and the dissection has to be meticulous with good haemostasis for this to be an obvious tissue plane.

Haemorrhage

Small, thin-walled vessels are frequently encountered over the anterior surface of the pancreas. These can be particularly troublesome over the head of the gland during the final dissection for mobilisation of the right colon for a radical right hemicolectomy. Ideally, the vessels should be identified and ligated before division using a fine ligature or a sealing device such as a Ligasure™ or Harmonic® scalpel. Unfortunately, they are often torn and subsequent diathermy coagulation is often unsuccessful with the vessel continuing to bleed. A fine Prolene® suture is often a better solution.

Parenchymal tears

An inadvertent minor tear in the pancreas, or an area of trauma that is not bleeding, may be best left alone, as sutures in the pancreas can sometimes compound an otherwise minor injury. There is still a risk of a pancreatic fistula and the area should be drained (see below). Larger tears should be treated in a similar manner to a transection.

Transection

A small portion of the tail of the pancreas may be removed either unintentionally during a splenectomy or as a planned excision when it is adherent to a colonic splenic flexure tumour. If a pancreatic duct is visible on the cut surface, it should be secured by suture ligation and the remainder of the parenchyma can then be oversewn or sealed with a haemostatic stapling device. Whichever method is employed, pancreatic leaks are common and the area should be drained.

Pancreatic drains

Any incision into the pancreas releases digestive enzymes with the potential for autodigestion. These enzymes inhibit healing and late leakage of pancreatic juice is common even when at first the closure appears sound. The enzymes cause intense inflammation and it is essential that any collection is drained. In view of the relatively high incidence of leaks, drains are still commonly used following proximal or distal pancreatic resections.

Pancreatic fistulae

A pancreatic leak may persist for many weeks as a pancreatic fistula. Eventually, most pancreatic fistulae will seal spontaneously, provided that there is no obstruction in the proximal pancreatic duct. The drain is left *in situ*, cut short and a stoma bag fixed over it so that the skin is protected and the volume of the fistula effluent can be measured.

PANCREATIC NEOPLASIA

Pancreatic neoplasms may arise from any of the cell types that constitute the pancreas. The biological behaviour of pancreatic neoplasms may range from benign indolent tumours to aggressive malignant cancers.

Benign pancreatic neoplasms

Benign tumours of the pancreas are rare. Cystic tumours are the most common benign neoplasms arising from cells of the exocrine pancreas. Rarely, a serous cystadenoma may grow to such a size that it causes local pressure effects or presents as a palpable mass. Most serous cystadenomas do not require surgery as malignant change is uncommon; however, they may require resection if symptomatic. In contrast, patients with a mucinous cystadenoma should be offered resection, as these tumours may have foci of invasive adenocarcinoma.

Malignant pancreatic neoplasms

Ductal adenocarcinoma is the commonest neoplasm, accounting for 90 per cent of all pancreatic neoplasms. It arises predominantly in the head of the gland and is the most prevalent of the *periampullary* tumours considered below. The commonest presenting features are jaundice, weight loss and pain. Progressive obstructive jaundice, frequently associated with marked and disabling pruritis, is due to compression or infiltration of the common bile duct as it passes through the head of the pancreas. Epigastric pain or discomfort is common and may radiate to the back, although the presence of back pain is a poor prognostic sign, suggesting advanced local disease. Adenocarcinoma of the body or tail of the pancreas typically presents with pain and weight loss and is almost invariably non-resectable because of either advanced local disease or the presence of metastases. The presence of an abdominal mass suggests non-resectable disease, although a malignant mass must be distinguished from a palpable enlarged gallbladder due to distal biliary obstruction (Courvoisier's sign).

Intraductal papillary mucinous neoplasm

Intraductal papillary mucinous neoplasms (IPMNs) are mucus-producing epithelial neoplasms, with a significant malignant potential, that can involve the main pancreatic duct or its side branches. Seventy percent of IPMNs involve the head of the gland and 5–10 per cent are spread diffusely throughout the gland, with the rest located within the body and tail. They most commonly present with symptoms related to pancreatic duct obstruction. Differentiating an IPMN from other cystic neoplasms radiologically can be challenging. However, with endoscopic ultrasound guidance, samples can be taken from the cystic fluid and solid components can be biopsied. When uncertainty remains regarding the risk of invasive disease, management requires careful assessment of co-morbidity and operative risk. However, the general principles are that patients with a main-duct IPMN should undergo resection, whereas a more selective approach should be taken in patients with a branch-duct IPMN based on symptoms, Ca 19-9 >25 U/ml, tumour size >3.5 cm and presence of mural nodules or thick walls. The main determinant of survival following resection is the presence or absence of invasive disease. If invasion is present, 5 year survival figures from different series vary between 13 and 60 per cent.

Endocrine neoplasms

Tumours arising from cells of the endocrine pancreas are very rare. They are often small and present with symptoms of endocrine hypersecretion rather than with symptoms from any mass effect of the growth itself. They may be benign or malignant, and solitary or multiple.

INSULINOMAS

The majority (90 per cent) of insulinomas are small (<1 cm diameter) and do not demonstrate malignant features, whereas larger lesions may metastasise. Most insulinomas are solitary and occur anywhere in the pancreas. Multiple pancreatic insulinomas also occur and have an association with the multiple endocrine neoplasia type 1 (MEN I) syndrome. Diagnosis of insulinoma may be difficult until it is suspected that the non-specific symptoms are related to hypoglycaemia. The diagnosis is confirmed biochemically by the inappropriate secretion of insulin (raised serum insulin and C-peptide levels). It is important to exclude factitious hypoglycaemia due to covert administration of insulin or oral hypoglycaemic agents. Preoperative localisation is not always possible, but CT and MRI can identify larger tumours and are useful in raising the suspicion of a malignant lesion. Endoscopic ultrasound is proving very sensitive for small tumours. Palpation alone at laparotomy will identify most tumours and, in combination with intraoperative ultrasound, it would be extremely rare that a small tumour in the pancreatic head would be missed after full mobilisation. However, if no tumour can be detected, blind resection is not recommended and the operation should be terminated. Most insulinomas can be successfully treated by enucleation of the tumour. If malignancy is suspected, a resection is indicated and this may also be advisable if the tumour abuts major vessels or the pancreatic duct.[1]

GASTRINOMAS

Patients with these gastrin-secreting tumours classically present with the Zollinger–Ellison syndrome (see Chapter 18, p. 299). Again, solitary tumours are usually sporadic while MEN 1-associated tumours are often multiple. However, in contrast to insulinomas, 60 per cent of gastrinomas are malignant. Gastrinomas are not confined to the pancreas and commonly occur in the wall of the duodenum. Somatostatin receptor scintigraphy is the preoperative localisation procedure of choice, but intraoperative palpation and ultrasound are again the most accurate localisation tools. The multiple tumours in MEN 1 are of particular concern and duodenotomy is recommended in all explorations so that the duodenal mucusa can be inspected. Both solitary sporadic tumours and multiple MEN 1-associated tumours can be simply enucleated from the pancreas or duodenum, but there is still controversy over the indications for a pancreaticoduodenectomy.[2] In the presence of metastases, resection of all tumours may still be undertaken for palliative control of the hypergastrinaemia.

Periampullary neoplasms

At the time of presentation and during assessment it is often not possible to determine the exact nature or tissue of origin of tumours arising in the region of the head of the pancreas, and indeed the distinction may be difficult even following histological analysis (Table 20.1). Therefore, neoplastic lesions found in the region of the head of the pancreas are frequently considered together as periampullary neoplasms.

STAGING OF PERIAMPULLARY NEOPLASMS

Preoperative staging investigations are undertaken in an attempt to reduce the number of patients subjected to a laparotomy at which a non-curative procedure is undertaken. Furthermore, preoperative assessment identifies co-morbidity, which would contraindicate major resectional surgery.

Table 20.1 *Malignant periampullary neoplasms.*

- Pancreatic adenocarcinoma
- Cholangiocarcinoma
- Adenocarcinoma of ampulla of Vater
- Duodenal adenocarcinoma

Staging investigations aim to determine the presence of either advanced local disease (e.g. involvement of a long segment of portal vein or superior mesenteric vein/artery) or metastases, which would generally be regarded as contraindications to resectional pancreatic surgery. Selected patients with only a short segment of involved portal vein may be considered for resection. An advanced tumour may be obvious clinically in a patient who has a palpable mass and ascites at presentation, but sophisticated imaging is necessary to demonstrate more subtle signs of irresectability, such as a cuff of tumour surrounding the mesenteric vein or local infiltration of tumour into the mesenteric vessels and the aorta. Triple phase contrast-enhanced CT is the most frequently used imaging modality, although it does have limitations. Although gross vascular involvement or occlusion by a pancreatic neoplasm may be easily determined by contrast-enhanced CT, the distinction between early vascular invasion and adherence of a neoplasm to the vessels may be difficult. In units where the philosophy is not to resect an involved portal vein this distinction is important; however, this differentiation is less of a concern if the surgeon is willing to consider portal vein resection. Furthermore, contrast-enhanced CT may not detect small hepatic metastases or low-volume peritoneal disease. For these reasons, a number of centres undertake laparoscopy and laparoscopic ultrasound in addition to contrast-enhanced CT.

PREOPERATIVE BILIARY DRAINAGE

The majority of patients with a periampullary neoplasm present with jaundice. These patients frequently undergo endoscopic retrograde cholangiopancreatography (ERCP) and insertion of a biliary stent in order to relieve the biliary obstruction. The benefits and risks of preoperative biliary drainage have been debated. Although prolonged obstructive jaundice is associated with a number of complications, it has been demonstrated that preoperative biliary drainage is associated with an increase in complications.[3] Therefore, if preoperative staging has shown a potentially resectable lesion, and a delay to surgical intervention can be avoided, it is reasonable to proceed without preoperative biliary drainage in patients with uncomplicated obstructive jaundice. In patients with acute cholangitis it is wise to achieve adequate biliary drainage and resolution of the acute cholangitis before contemplating resection. If preoperative biliary drainage is undertaken, then surgical intervention should be delayed for 3–4 weeks to allow resolution of the pathophysiological disturbances associated with obstructive jaundice (see also Chapter 19).

PREOPERATIVE TISSUE DIAGNOSIS

Preoperative histological confirmation of a periampullary neoplasm is not mandatory before undertaking resectional surgery. The indication for surgery is based on a clinical picture and radiological imaging consistent with pancreatic neoplasia. Radiologically-guided percutaneous core biopsy is not generally recommended because of concerns about tumour implantation along the biopsy track and false-negative results. Upper gastrointestinal endoscopy may allow confirmatory biopsies to be obtained in patients with duodenal and ampullary tumours. Furthermore, a cytological diagnosis may be achieved from biliary brushings or endoscopic ultrasound-guided fine-needle aspiration. Negative cytological and histological results should not in themselves contraindicate resection if significant concerns still exist regarding the possibility of an underlying malignancy. Indeed, up to 10 per cent of pancreaticoduodenectomies undertaken for presumed malignancy are found to have non-neoplastic pathologies (e.g. chronic pancreatitis, inflammatory bile duct stricture).

Pancreaticoduodenectomy

Pancreaticoduodenectomy is the procedure of choice for surgery with curative intent in patients with a periampullary neoplasm. This technique was described by Whipple in 1946, and the resection bears his name.[4] The extent of the resection is shown diagrammatically in Figure 20.2. It is a major undertaking, and although current published series report mortality rates under 5 per cent, it should be remembered that during the 1960s mortality rates approached 25 per cent. Therefore, in an era of increasing sub-specialisation within general surgery, pancreatic resectional surgery should be concentrated in specialist pancreatic units.

Indications

Indications for pancreaticoduodenectomy include:

- Resectable periampullary neoplasms.
- Chronic pancreatitis with disease confined to the head of the gland.

Operative procedure

Excellent access to the pancreas is afforded by a transverse upper abdominal or roof-top incision. To aid exposure, fixed costal margin retraction is employed, while the lower wound edge may be sutured to the lower portion of the anterior abdominal wall. A midline incision may be useful in patients with a high costal margin.

A full laparotomy is undertaken, with special attention directed towards the exclusion of peritoneal and hepatic metastases, the presence of which would be a contraindication to a major procedure. Invasion of tumour through to the infracolic aspect of the transverse mesocolon or invasion into the portal vein or superior mesenteric vein generally precludes resection, although some centres advocate portal vein resection when this is involved. Intraoperative ultrasound may be utilised in the assessment of vascular invasion and liver metastases.

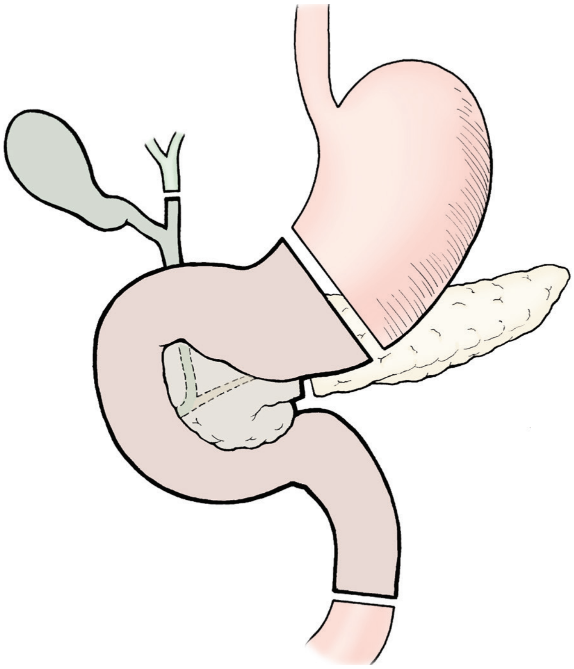

Figure 20.2 *The extent of the resection in a standard Whipple's pancreaticoduodenectomy. In a pylorus-preserving resection the proximal intestinal tract transection is through the proximal duodenum.*

The ascending colon and hepatic flexure are fully mobilised towards the midline. The duodenum is completely Kocherised, lifting the head of the pancreas off the inferior vena cava and anterior surface of the aorta. The lesser sac is entered through the mid portion of the gastrocolic omentum, with serial ligation and division of epiploic vessels, or entered by dissection of the greater omentum from the transverse colon (see Chapter 14 and Figure 14.4). The lesser sac dissection is continued to the right towards the head of the pancreas, allowing identification of the right gastroepiploic vessels. Continuation of the dissection of the colon from the 2nd and 3rd parts of the duodenum across the anterior surface of the pancreas reveals the superior mesenteric vein (SMV) with the artery lying on its left lateral aspect. As the SMV passes over the uncinate process it receives a number of fragile veins on its anterior surface, including the right gastroepiploic vein. These veins are easily torn and should be ligated and divided at the earliest opportunity in order to prevent bothersome bleeding.

The gallbladder is dissected from the gallbladder bed in a fundus-first fashion, but the cystic duct is not divided. The cystic artery is ligated and divided. The anterior peritoneum of the hepatoduodenal ligament is divided with mobilisation of tissues down towards the duodenum. The common hepatic duct is identified and transected above the insertion of the cystic duct. Any previously placed biliary stent is removed or pushed down into the specimen, and the distal common hepatic duct closed. Transection of the common hepatic duct exposes the portal vein lying behind it. The peritoneum overlying the lateral and posterior edges of the portal vein is divided. Care must be employed to avoid injury to an accessory or replaced right hepatic artery. The common hepatic artery and the gastroduodenal artery (GDA) are dissected free in a retrograde fashion. Tissue cleared from the vessels is removed *en bloc* with the resection specimen. The GDA is temporarily occluded in order to confirm that arterial inflow to the liver is maintained. If the pulse in the hepatic artery is lost on occlusion of the GDA, pancreaticoduodenectomy is not possible without vascular reconstruction. The GDA is then divided between ligatures and the stump is suture ligated.

The site of the proximal intestinal tract transection depends on whether a classical Whipple's procedure or a pylorus-preserving pancreaticoduodenectomy (PPPD) is being undertaken. PPPD was initially introduced in an attempt to reduce postoperative complications due to dysfunctional gastric emptying following classical Whipple's resection.[5] However, randomised trials have not demonstrated superiority of one technique over the other, and therefore for the most part the choice is operator dependent. However, for tumours abutting the pylorus, a classical Whipple's procedure must be performed in order to obtain adequate oncological clearance.

Antrectomy is performed in a classical Whipple's procedure. At the level of the incisura, the lesser omentum is divided onto the lesser curve of the stomach, ligating the vessels running parallel to the gastric wall. A suitable point is identified on the greater curve of the stomach and the gastroepiploic arcade is divided. The stomach is then transected. The use of a linear cutting stapling device simplifies the division.

The small bowel is divided in the proximal jejunum. The small bowel proximal to the transection line is devascularised with serial ligation and division of the vessels as they enter the wall of the small bowel. Two layers of vessels may be identified in the region of the distal duodenum and proximal jejunum. Peritoneum around the duodenojejunal flexure is divided, allowing the small bowel, distal to where it has been transected, to be passed through the transverse mesocolon into the supracolic compartment.

The SMV is identified. Using careful blunt dissection, the plane between the SMV and the neck of the pancreas is developed. Continued dissection in this plane frees up the SMV and portal vein. Invasion of the SMV or portal vein most often denotes non-resectable disease, although portal vein resection and reconstruction may occasionally be appropriate. The tunnel behind the neck of the pancreas marks the pancreatic transection line. Stay sutures are placed on the superior and inferior borders of the pancreas on either side of the proposed transection line (Figure 20.3). These sutures facilitate the control of bleeding following pancreatic transection. Transection of the pancreas is undertaken using a scalpel or diathermy. Haemostasis is achieved by underrunning bleeding pancreatic vessels.

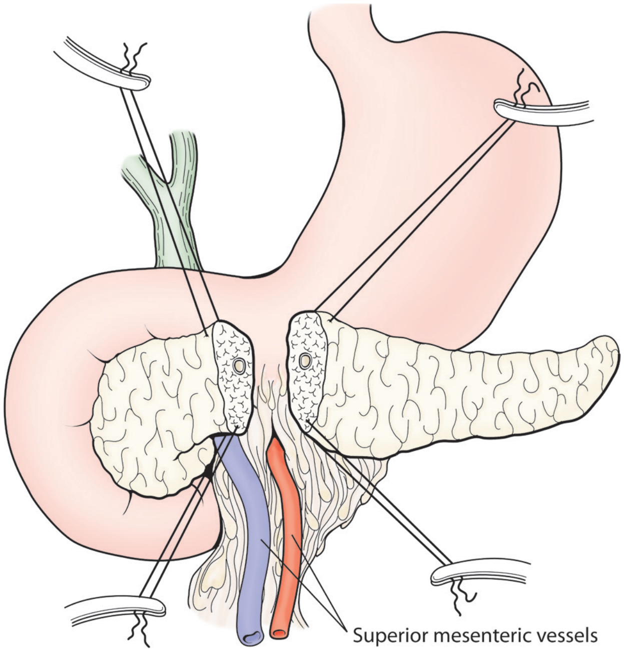

Figure 20.3 *The tunnel behind the neck of the pancreas and in front of the superior mesenteric vessels marks the line of the pancreatic transection. Stay sutures in the pancreas are useful at this stage.*

Tissue between the pancreatic head and the right border of the SMV and portal vein can be serially ligated and divided, or transected using tissue sealing/dividing devices such as UltraCision®, allowing delivery of the resection specimen. During this stage care must be taken to ensure that the SMA is not rotated around to the right lateral aspect of the SMV, placing it at risk of injury.

Following resection, intestinal continuity with the stomach, biliary tree and pancreas must be restored. Numerous methods of reconstruction have been described. The pancreaticoenteric anastomosis is at greatest risk of failure, and therefore a number of techniques for this have been tried in an attempt to reduce the risk of anastomotic leakage, although none has been proven to be clearly more effective than another. One recommended method is a reconstruction to a single loop of small bowel, the pancreaticojejunostomy being fashioned just distal to the small-bowel transection line, followed by the hepaticojejunostomy and finally the gastrojejunostomy (Figure 20.4). The proximal jejunum is brought up through a window in the transverse mesocolon. An end-to-side pancreaticojejunal anastomosis is fashioned using a single-layer interrupted parachute technique with an absorbable monofilament suture. Mucosa-to-mucosa apposition is straightforward in patients with a dilated pancreatic duct and a firm pancreas, but in patients with a non-obstructed pancreatic duct and normal pancreatic parenchyma, formation of the pancreaticojejunal anastomosis requires meticulous technique. Bilioenteric continuity is restored by an end-to-side hepaticojejunostomy fashioned using a single-layer interrupted parachute technique with an

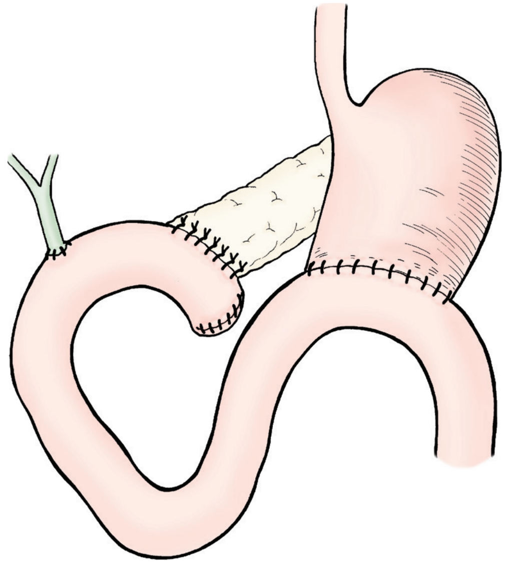

Figure 20.4 *A satisfactory arrangement for the anastomoses of stomach, bile duct and pancreas to the jejunum.*

absorbable monofilament suture (see Chapter 19 and Figure 19.11). The gastrojejunostomy is fashioned using a single-layer, full-thickness technique with an absorbable monofilament suture. A nasogastric tube may be retained postoperatively; however, stents are not placed across the pancreatic or biliary anastomoses. Two drains, one anterior and one posterior to the pancreaticojejunal anastomosis, can be placed in such a fashion as to cover all three anastomoses. However, it should be noted that the routine use of drains has been questioned.

Despite meticulous surgery, there is a high incidence of failure of pancreaticoenteric anastomoses. *Octreotide* is a somatostatin analogue that reduces pancreatic secretion, and has been used prophylactically following pancreatic surgery in an attempt to reduce the risk of complications such as pancreaticojejunal anastomotic leak or pancreatic fistula. However, although randomised trials have been undertaken, the role of prophylactic octreotide in reducing the risk of pancreaticojejunal anastomotic failure is still not clear. Prophylactic octreotide may be beneficial in high-risk situations where the pancreas is soft and the pancreatic duct is not dilated, but there is probably no indication for using it routinely. Octreotide may also be prescribed with therapeutic intent in order to treat complications of pancreatic disease and surgery.

Palliative surgery

The majority of patients presenting with pancreatic cancer have non-resectable disease because of local vascular invasion, metastatic disease or significant medical co-morbidity. Current management aims to identify contraindications to resection prior to laparotomy and to provide appropriate palliation in those patients. Although it has been suggested that surgical palliation should be undertaken in patients who are felt to have a good chance of prolonged survival, studies have failed to demonstrate any survival benefit from surgical palliation when compared with non-operative procedures such as endoscopic or percutaneous biliary stenting (see Chapter 19).

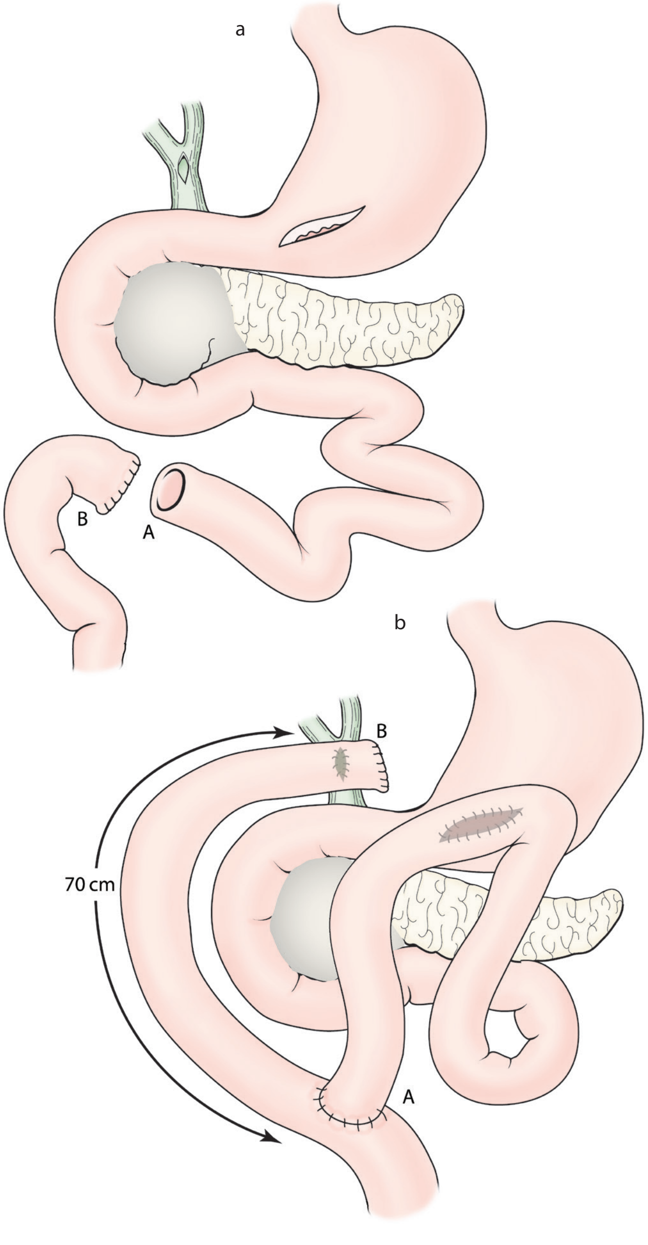

Figure 20.5 *Palliative double bypass gastroenterostomy and hepaticojejunostomy Roux-en-Y. (a) The choledochotomy and gastrotomy incisions have been made and the proximal jejunum has been divided. (b) The distal jejunum is used to form the hepaticojejunostomy. A 70-cm Roux loop is recommended. The proximal jejunum is used to create a gastroenterostomy proximal to the enteroenterostomy. Although both the hepaticojejunostomy and the gastrojejunostomy are shown diagrammatically in the illustration, they are both onto the posterior wall of the jejunum and obscured from view.*

In patients presenting with evidence of non-resectable disease and gastric outlet obstruction, a palliative gastroenterostomy should be performed. Endoscopic duodenal stenting is another alternative. Percutaneous biliary stenting may be undertaken at a later date if obstructive jaundice develops. In patients undergoing open gastroenterostomy, a hepaticojejunostomy Roux-en-Y should also be performed. Cholecystojejunostomy is to be avoided because it is associated with a higher failure rate when compared with hepaticojejunostomy, as the cystic duct frequently becomes occluded with progression of the underlying malignancy.

For patients in whom a radical resection was planned but non-resectable disease is discovered at laparotomy, a gastroenterostomy and hepaticojejunostomy Roux-en-Y double bypass should be undertaken (Figure 20.5). Further descriptions of these procedures are provided in Chapters 17 and 19.

Distal pancreatectomy

Indications

Indications for distal pancreatectomy include:

- Neoplasia involving the body/tail of the pancreas.
- Chronic pancreatitis affecting the body/tail of the pancreas only.
- Pancreatic pseudocyst or pancreatic fistula arising from a pancreatic duct disruption in the body/tail of the pancreas.

Because of the high probability of undertaking a splenectomy at the time of distal pancreatectomy, patients should have preoperative immunisations if time allows, as discussed later in the chapter (see Splenectomy).

Operative procedure

An upper abdominal transverse incision extending more to the left provides excellent exposure. Alternatively, an upper midline incision may be employed.

A *distal pancreatectomy with splenectomy* is represented diagrammatically in Figure 20.6. The lesser sac is entered through the gastrocolic omentum, allowing exposure of the pancreas. The whole length of the pancreas is exposed through serial ligation and division of the epiploic vessels. Access to the lesser sac may also be obtained following dissection of the greater omentum from the transverse mesocolon, and the vascular arcade along the greater curve is preserved. The short gastric vessels are ligated and divided, allowing separation of the spleen from the stomach. The splenic flexure of the colon is mobilised, which allows full access to the tail of the pancreas.

When possible, the splenic artery at the level of the upper border of the pancreas is isolated and followed towards its origin. Ligation of the splenic artery at the level of planned transection may be undertaken prior to dissection of the spleen and tail of the pancreas in order to reduce blood loss. The lateral peritoneal reflection of the spleen is divided, allowing the organ to be lifted forward. This manoeuvre opens up an avascular plane of loose areolar tissue between the pancreas and the other structures of the retroperitoneum, allowing easy dissection behind the pancreas and splenic vessels. Once the previously designated transection point has been reached, the splenic vessels are ligated (if this has not been done already) and the pancreas transected, allowing delivery of the operative specimen. Dissection of the pancreas from the retroperitoneum may also be undertaken in a proximal to distal fashion, although dissection in the correct plane may be more difficult to achieve.

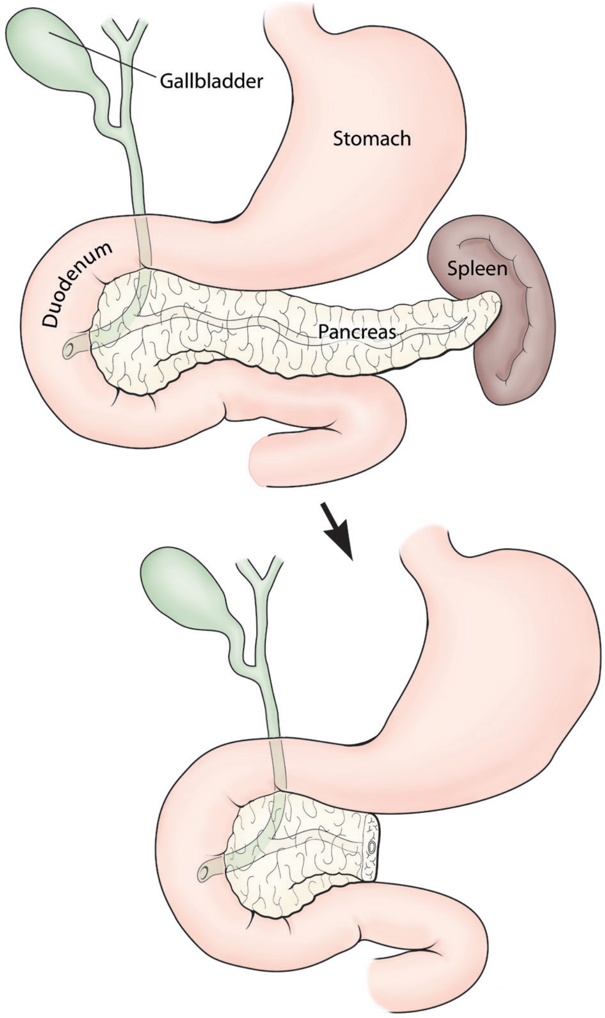

Figure 20.6 *Distal pancreatectomy.*

A number of techniques have been described that aim to reduce the risk of pancreatic fistulae from the pancreatic resection margin. These include oversewing of the main pancreatic duct, placing horizontal mattress sutures through the pancreatic stump and transection of the pancreas using a transverse linear stapler. No single technique has been demonstrated to be superior to any other.

In a *spleen-preserving distal pancreatectomy* the splenic vessels are not divided and the distal pancreas is dissected from these vessels with ligation of branches entering the pancreas.

An alternative technique for splenic preservation maintains blood supply to the spleen through the short gastric vessels while dividing the splenic artery and vein immediately distal to the tail of the pancreas.

Laparoscopic distal pancreatectomy is becoming increasingly common, especially in the management of benign pancreatic lesions.

SURGERY FOR ACUTE PANCREATITIS

The initial management of acute pancreatits is supportive. Severe disease may be complicated by multiple organ failure requiring cardiovascular support, invasive ventilation and renal replacement therapy. Nutritional support is also important and should, if possible, be provided by the enteral route; nasogastric or nasojejunal feeding may be required. Ultrasound examination for gallstones should be undertaken.[6] Other than cholecystectomy, following recovery from gallstone-induced acute pancreatitis, intervention in acute pancreatitis is confined to specific complications (infected pancreatic necrosis, haemorrhage and complicated pancreatic pseudocysts).

Surgical intervention in acute pancreatitis should be tempered by the knowledge that evidence suggests that lesser and later interventions are associated with improved outcomes. Early laparotomy with early removal of pancreatic necrosis is known to worsen outcome and evidence is accruing to suggest that later intervention in the setting of infected necrosis is best undertaken using a minimally-invasive approach rather than undertaking the more traditional necrosectomy. Life-threatening haemorrhage from a pseudoaneurysm is also better treated by radiographic embolisation rather than surgical exploration. It should, however, be noted that minimally-invasive and radiological techniques may not be suitable in all cases and that timely surgical intervention can be life saving.

ERCP IN GALLSTONE-INDUCED ACUTE PANCREATITIS

Early ERCP and endoscopic sphincterotomy within 48 hours of disease has only been shown to be beneficial in patients with co-existing cholangitis. Routine ERCP prior to cholecystectomy is not indicated for patients with gallstone-induced acute pancreatitis and normal liver function tests. Intraoperative cholangiography can be undertaken at cholecystectomy and if common bile duct stones are demonstrated, they can be managed in the usual way by either duct exploration or postoperative ERCP and stone extraction.

CHOLECYSTECTOMY

Cholecystectomy should be undertaken in all patients with gallstone-induced acute pancreatitis, unless significant contraindications exist. In this latter group of patients, endoscopic sphincterotomy should be undertaken in order to reduce the risk of recurrent episodes of acute pancreatitis, although it should be noted that sphincterotomy alone will not reduce the risk of gallstone-induced gallbladder problems.

For patients with gallstone-induced mild acute pancreatitis, cholecystectomy should be performed during the index admission or within 2 weeks. However, in patients with severe disease, a cholecystectomy should be deferred until it is clear that surgical intervention for a complication of the attack of acute pancreatitis is not required.

Pancreatic necrosectomy

Pancreatic necrosis can be demonstrated on CT scan, but the presence of necrosis is not in itself an indication for surgical intervention. Current guidelines state that pancreatic necrosectomy should be undertaken for infected pancreatic necrosis and for symptoms and signs of sepsis. Infected pancreatic necrosis may be confirmed by the microbiological examination of fine-needle aspirates of pancreatic necrosis or the identification of radiological signs of infection such as the presence of extraluminal retroperitoneal gas. Patients requiring surgical intervention for complicated severe acute pancreatitis should, if possible, be managed in appropriate specialised units.

The timing of surgical intervention seems to be crucial. Studies suggest that early intervention (less than 2 weeks from onset of disease) is associated with increased mortality, mostly related to haemorrhagic complications. In contrast, delayed intervention allows the liquefaction of pancreatic necrosis and facilitates both minimally-invasive necrosectomy and open blunt necrosectomy. In addition, the area of necrosis may mature over several weeks to form a pseudocyst, which can be more simply drained. The management of pseudocysts is discussed later in this chapter. Delay is therefore preferable and some centres will continue conservative management even for infected pancreatic necrosis if the patient remains stable.

Minimally-invasive pancreatic necrosectomy[7]

Percutaneous necrosectomy involves the radiological placement of a percutaneous drain into the infected pancreatic necrosis, preferably using a retroperitoneal approach. In theatre and under general anaesthesia, the retroperitoneal drain is changed for a guide wire and the track is dilated, allowing insertion of an operating nephroscope through which the pancreatic necrosectomy is undertaken, taking great care to minimise the risk of haemorrhage. Once completed, a large drain is inserted along the track into the lesser sac cavity. It is possible to place two drains down the track, thereby allowing post-procedure lesser sac lavage. Further 'drain track' necrosectomies may be performed following the initial percutaneous necrosectomy. This is probably the optimal approach, although endoscopic and laparoscopic approaches have also been described and the choice of minimally-invasive procedure is determined by local expertise. Only the very occasional patient requires an open procedure.

Open pancreatic necrosectomy

An upper abdominal transverse incision provides satisfactory access for a necrosectomy, with the addition of a cholecystectomy when indicated.

The pancreas is best approached through the gastrocolic omentum, although entry into the lesser sac through the transverse mesocolon may sometimes be required. If entry is made through the transverse mesocolon, great care must be taken to avoid the middle colic vessels. Once identified, samples of necrotic tissue are sent for microbiological culture. Pancreatic and peripancreatic necrotic tissue is removed using a number of techniques, including blunt dissection and hydrodissection with saline expelled from a 50-ml catheter tip syringe. The removal of necrotic material should be undertaken with great care as injudicious force may provoke catastrophic haemorrhage.

If practical, a feeding jejunostomy tube should be inserted for postoperative enteral feeding. Consideration should also be given to the insertion of a decompressing gastrostomy. Cholecystectomy should be performed in all patients with gallstone-induced acute pancreatitis. However, in some patients cholecystectomy may not be safely performed at the time of necrosectomy, and in these circumstances either an interval or subtotal cholecystectomy is warranted.

A number of options exist for the management of the pancreatic bed following necrosectomy:

- *Simple drainage*. Tube drains are placed into the lesser sac.
- *Postoperative irrigation*. The drains are placed in such a fashion as to allow instillation of fluid through one drain with exit by at least one other drain. It is best to keep the opening into the lesser sac small in order to minimise any escape of fluid into the rest of the peritoneal cavity. Postoperative lesser sac irrigation may be started 24 hours after necrosectomy. A variety of fluids and flow rates have been used for this.
- *Planned 'second-look' procedures*. The abdominal wound is closed, usually after packing of the lesser sac. On occasion, closure may only be achieved through the use of a prosthetic material. A planned second-look laparotomy and further debridement if necessary are performed at 24–48 hours.
- *Open laparostomy*. The abdominal wound is left open, allowing free entry into the lesser sac. 'Marsupialisation' of the lesser sac may also be undertaken; the stomach is sutured to the upper edge of the abdominal wound and the transverse colon to the lower edge. Further lesser sac debridement may then be undertaken in the intensive care environment, and need not be performed in theatre. Unfortunately, this management strategy can be complicated by secondary haemorrhage, and the development of an incisional hernia is almost inevitable.

SURGERY FOR CHRONIC PANCREATITIS

The majority of patients with chronic pancreatitis do not require surgical intervention and may be managed conservatively. Conservative management consists of elimination of the aetiological agent, where possible, and medical treatment of the complications, namely pain and pancreatic exocrine and endocrine insufficiency. Where alcohol excess is the cause, abstinence from alcohol must be encouraged. Analgesics appropriate to the level of pain should be prescribed, although this may result in both physical and psychological dependence on opiate analgesia. Exocrine insufficiency is treated by the prescription of pancreatic enzyme supplements (e.g. Creon®). Endocrine insufficiency may require prescription of oral hypoglycaemic agents or insulin therapy. A multidisciplinary approach is frequently required.

Chronic pain is a common feature. Although pain may arise as a consequence of a specific complication of chronic pancreatitis, such as a pseudocyst, for the majority of patients the cause of the pain is not clear and management may be difficult. The proposed mechanisms of pain include increased pancreatic duct and/or pancreatic parenchymal pressure, pancreatic ischaemia, pancreatic fibrosis, alteration of pancreatic nerve function and, most recently, a neuroimmune interaction. For patients with a specific complication giving rise to pain, management is directed towards that complication (see Table 20.2). Procedure selection for pain is dependent on the presence or absence of pancreatic duct dilatation and pancreatic inflammation. A dilated duct demonstrated

Table 20.2 *Surgical management of pain in chronic pancreatitis.*

		Involvement of the head of the pancreas?	
		Yes	No
Dilated main pancreatic duct?	Yes	Lateral pancreaticojejunostomy with partial excision of the pancreatic head (Frey)	Lateral pancreaticojejunostomy (Puestow, Partington-Rochelle)
	No	Duodenal-preserving pancreatic head resection (Beger) or Pancreaticoduodenectomy	Medical management

on CT scan, especially if there are also stones within the duct, suggests an obstructive component. Drainage procedures are undertaken in patients with a dilated pancreatic duct, while resectional procedures are undertaken for inflammation. Drainage and resectional procedures may be combined. For patients without pancreatic inflammation and a normal-sized pancreatic duct, the role of pancreatic surgery is uncertain. A period of abstinence from alcohol is mandatory for those in whom alcohol is the aetiological agent before surgical intervention for pain is considered. Significant improvement in both symptoms and radiological signs may be obtained following withdrawal of alcohol.

Imaging

CT is the mainstay of pancreatic imaging and may demonstrate features such as pancreatic calcification, inflammation and pancreatic duct dilatation. It may also detect complications such as pseudocysts, false aneurysms and splenic vein thrombosis. ERCP may be undertaken to delineate pancreatic duct morphology and identify pancreatic duct strictures and sites of duct disruption. Magnetic resonance cholangiopancreatography (MRCP) may also identify these features and is being used with increasing frequency, although ERCP allows both dynamic interpretation of duct irregularities and endoscopic intervention where appropriate.

Surgical procedures in chronic pancreatitis

PARTINGTON–ROCHELLE OR PUESTOW PROCEDURE: LATERAL PANCREATICOJEJUNOSTOMY[8]

Lateral pancreaticojejunostomy aims to provide drainage of the main pancreatic duct. The operation may be undertaken in patients with intractable pain and radiological evidence of pancreatic duct dilatation with or without pancreatic duct calculi. In addition to treating the pain, there is some evidence that early pancreatic duct drainage may reduce the risk of development of pancreatic endocrine insufficiency.

Operative procedure

The full length of the pancreas is approached via the lesser sac after division of the gastrocolic omentum. Although the bulging pancreatic duct may be seen through the anterior surface of the pancreas, aspiration with a syringe and needle ('seeker' needle) is frequently used to identify it. The duct is then incised using diathermy and opened along its length into the head of the gland. The insertion of a probe or Lahey forceps may facilitate opening of the duct. A Roux loop is fashioned and brought up into the lesser sac through the transverse mesocolon to the right of the middle colic vessels. The blind end of the Roux loop is laid on the tail of the pancreas (Figure 20.7). A side-to-side pancreas to small bowel anastomosis is fashioned using a single-layer technique with absorbable sutures (e.g. polydioxanone, PDS®). If access is difficult, the blind end of the Roux loop may be parachuted into position. The original descriptions are of an anastomosis between the edges of the opened jejunum and the capsule of the pancreas on either side of the opened duct. If technically possible, mucosa-to-mucosa apposition is now considered superior, but in a grossly thickened gland this may not be an option. Intestinal continuity is restored with an enteroenterostomy 40 cm below the transverse mesocolon.

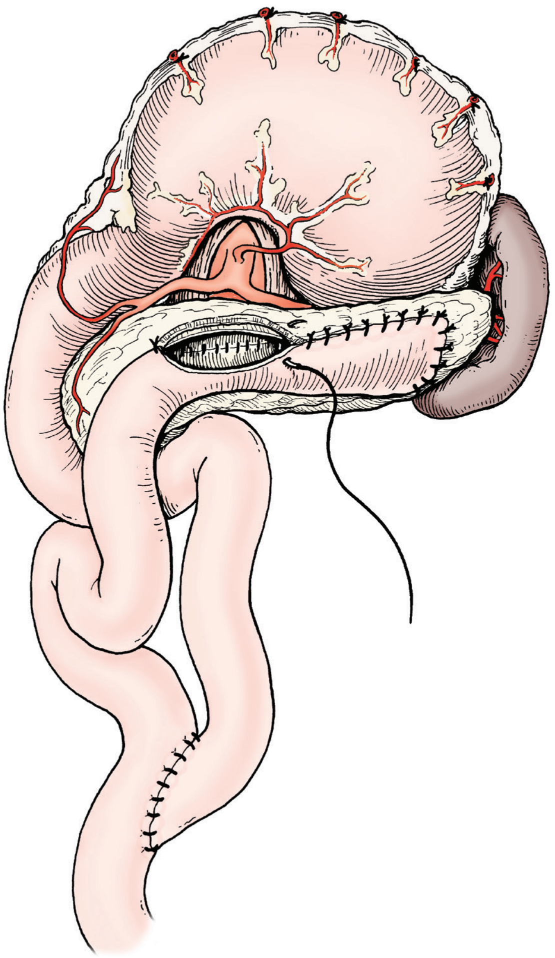

Figure 20.7 *Lateral pancreaticojejunostomy – 'Partington–Rochelle'. The pancreatic duct is opened along its length and anastomosed side-to-side to a Roux loop of jejunum.*

In the original Puestow operation the drainage of the distal duct was combined with a splenectomy and distal pancreatectomy, but the later modification by Partington and Rochelle preserves both the pancreatic tail and the spleen.

Frey's procedure

This operation is a modification of the lateral pancreaticojejunostomy with partial excision (or coring out) of the pancreatic head.[9] It combines a pancreatic duct drainage procedure with resectional surgery, and is indicated in patients with an inflammatory mass in the head of the pancreas and an associated dilated pancreatic duct. The Roux

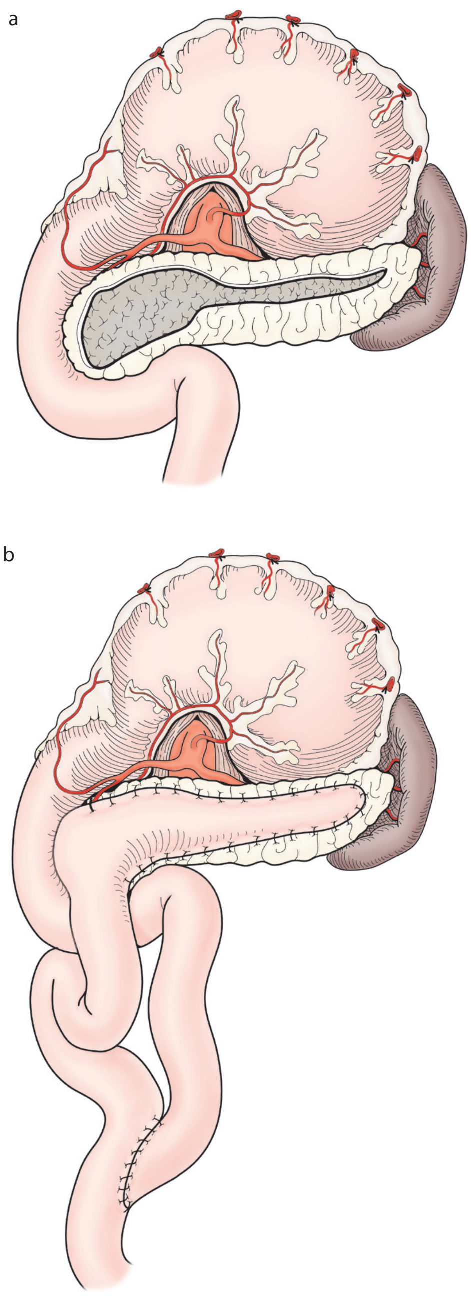

Figure 20.8 *Frey's procedure. (a) The pancreatic duct is opened along its length and the pancreatic head cored out. (b) A Roux loop is used for a side-to-side pancreaticojejunostomy both to the opened duct and to the edges of the defect in the head.*

loop is anastomosed to the opened duct and to the edges of the pancreatic defect left by the resection of the inflammatory mass in the pancreatic head (Figure 20.8).

BEGER'S PROCEDURE: DUODENUM-PRESERVING PANCREATIC HEAD RESECTION[10]

This is an alternative procedure for a symptomatic inflammatory mass in the head of the pancreas that has failed to respond to conservative treatment; it is less commonly performed than a Frey procedure. This operation is not appropriate where concern exists regarding the possibility of an underlying malignancy, in which case a pancreaticoduodenectomy is the procedure of choice.

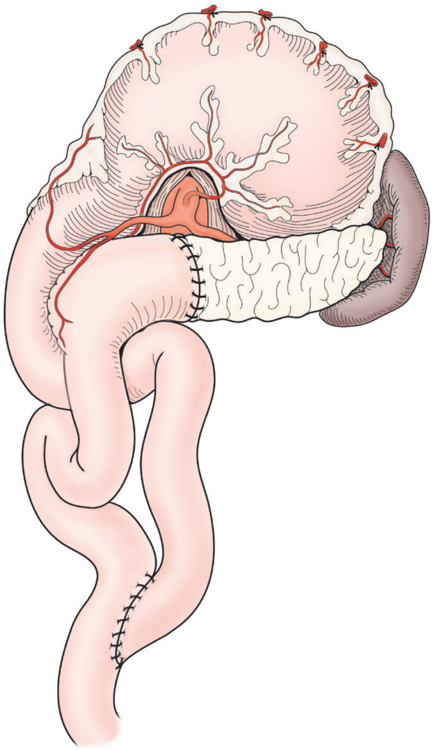

Figure 20.9 *Duodenum-preserving pancreatic head resection – Beger's procedure. A Roux loop of jejunum is anastomosed to the site of the pancreatic head resection.*

Operative procedure

The pancreatic head is resected leaving the duodenum *in situ*. The end of the Roux loop is anastomosed to the transected neck of the pancreas (Figure 20.9). In cases with very severe inflammation, particularly in patients with cholestasis, the posterior limit of the resection in the region of the head of the pancreas may include the anterior wall of the common bile duct. The edges of the pancreatic defect left by the resection are then used for the anastomosis to the Roux loop.

PANCREATICODUODENECTOMY

A pancreaticoduodenectomy is indicated for patients in whom an isolated inflammatory mass in the head of the pancreas exists, especially if it is associated with either gastric outlet or biliary obstruction. In these patients there is usually concern about the possibility of a pancreatic neoplasm. Indeed, focal chronic pancreatitis is part of the differential diagnosis for a periampullary neoplasm. In patients with chronic pancreatitis the dissection is made difficult because of the fibrous obliteration of the tissue planes following episodes of inflammation. However, the pancreaticojejunal anastomosis is made easier because of pancreatic fibrosis.

Some authors advocate pylorus-preserving pancreaticoduodenectomy over a Whipple's procedure in chronic pancreatitis, although there is no good evidence as to its superiority.

TOTAL PANCREATECTOMY

There are few indications for total pancreatectomy in chronic pancreatitis. This is due in part to the significant metabolic and nutritional complications of total pancreatectomy. Diabetes mellitus is inevitable after total pancreatectomy and is often 'brittle', with poor glycaemic control. Total pancreatectomy has, however, been advocated for patients with hereditary pancreatitis who are at high risk of developing a pancreatic neoplasm.

COMPLICATIONS OF NON-NEOPLASTIC PANCREATIC DISEASE

Biliary obstruction

Biliary obstruction may arise as a consequence of a pseudocyst or an inflammatory mass in the head of the pancreas. It may also be due to fibrosis of the bile duct as a consequence of recurrent episodes of inflammation. Whereas a pseudocyst that is causing biliary obstruction from pressure can simply be drained, inflammation and fibrosis require other strategies. Resectional surgery of an inflammatory mass or bile duct stricture is indicated if there is concern about neoplasia. However, because of its lower associated morbidity and mortality rates, a bypass procedure in the form of a hepaticojejunostomy Roux-en-Y is indicated when there is no concern about malignancy (see Chapter 19). Although biliary stenting may provide temporary relief of jaundice and allow time for the resolution of any inflammatory element, it is not a long-term solution. Prolonged biliary stenting is associated with recurrent episodes of acute cholangitis and secondary biliary cirrhosis.

Gastric outlet obstruction

A pseudocyst or inflammatory mass in the head of the pancreas may give rise to gastric outlet obstruction. In some cases, gastric outlet obstruction may improve with conservative measures, including the withdrawal of alcohol where appropriate. In patients requiring surgical intervention, an attempt should be made to treat the cause of the obstruction, although usually a gastroenterostomy is undertaken.

Splenic vein thrombosis

Pancreatic inflammation can cause splenic vein thrombosis, which may lead to segmental portal hypertension. Haemorrhage from gastric fundal varices and hypersplenism are possible sequelae. Operative intervention should be considered in patients with complications of splenic vein thrombosis, and splenectomy is curative. Portal vein thrombosis and its ensuing complications can also occur.

Pancreatic pseudocysts

A pancreatic pseudocyst is a non-epithelialised collection of pancreatic juice that is surrounded by fibrous or granulation tissue. Pseudocysts may arise following acute pancreatitis, chronic pancreatitis or trauma. In patients with acute pancreatitis, a pancreatic pseudocyst must be differentiated from an acute fluid collection, which does not have a well-developed wall and occurs within 6 weeks of the initial episode of acute pancreatitis. Although acute fluid collections may mature into pseudocysts, their initial management is conservative unless they become infected.

The differential diagnosis of a pancreatic pseudocyst includes a pancreatic cystic neoplasm. It is therefore important to be confident that a pancreatic cystic lesion is indeed a pseudocyst before embarking on either conservative management or operative drainage. Although the presence of radiological features such as septation, cyst wall calcification, focal wall thickening and papillary projections should raise concern about a diagnosis of neoplasia, perhaps the most important guide to making the correct diagnosis of a pancreatic pseudocyst is a prior history of pancreatitis.

The factors discussed below influence decisions in the management of pancreatic pseudocysts.

Size

Traditional teaching was that pseudocysts of more than 6 cm in diameter or those present for more than 6 weeks required operative intervention. However, observational studies suggest that asymptomatic pseudocysts may be managed conservatively and followed with serial imaging. Intervention is warranted in symptomatic, complicated or enlarging pseudocysts.

Acute or chronic status

Pseudocysts arising in the context of acute pancreatitis may differ from those developing as a consequence of chronic pancreatitis. Because of the peripancreatic inflammation and necrosis that are associated with acute pancreatitis, pseudocysts that arise following an episode of acute pancreatitis frequently contain debris or necrotic material. In contrast, debris in a pseudocyst secondary to chronic pancreatitis is unusual. It should be noted that the amount of necrotic material is frequently underestimated on CT scan, but can be readily appreciated by using ultrasonography. The presence of necrotic material within a pseudocyst influences management, as endoscopic drainage may be inadequate to drain the cyst completely, with resultant development of infected pancreatic necrosis or a pancreatic abscess. Thus, for patients with an appreciable volume of pancreatic necrosis and debris, open or laparoscopic pseudocyst drainage with debridement of necrotic material may be the procedure of choice.

Spontaneous resolution of pseudocysts in the setting of acute pancreatitis occurs more frequently than in those related to chronic pancreatitis.

Pancreatic duct morphology

Endoscopic pancreatic duct stenting may be utilised in the management of patients with either pseudocysts or pancreatic ascites, especially those arising in the context of chronic pancreatitis. Successful treatment is dependent on the satisfactory determination of pancreatic duct morphology and in particular the presence and location of pancreatic duct strictures and disruption. Pancreatic duct disruption distal to a pancreatic duct stricture that cannot be crossed with a stent will not respond to endoscopic management. However, if there is no pancreatic duct stricture, decompression of the pancreatic duct with a stent should permit healing of the duct disruption and resolution of the pseudocyst. In this situation the stent does not have to traverse the pancreatic duct defect; indeed, effective drainage may be achieved with a small transampullary stent.

Extent of the cyst

Internal drainage of pancreatic pseudocysts should be between a dependent portion of the pancreatic pseudocyst and the intestinal tract, regardless of the methods used. For pseudocysts confined to the lesser sac, adequate drainage may be achieved by internal drainage into the stomach. If the pseudocyst extends down behind the transverse mesocolon into the infracolic compartment, drainage should be by the formation of a pseudocyst-jejunostomy Roux-en-Y.

DRAINAGE OF PANCREATIC PSEUDOCYSTS

Prior to any intervention for a pancreatic pseudocyst, up-to-date abdominal imaging should be available, especially as spontaneous resolution can occur. The choice of technique may depend on local expertise, but increasingly endosopic and laparoscopic interventions are employed.

Endoscopic internal drainage

Internal drainage of pseudocysts can be undertaken endoscopically with a transmural stent inserted to achieve either transgastric or transduodenal drainage. This technique is suitable for pseudocysts occurring in either the pancreatic head or body and with a distance of less than 1 cm between the enteric lumen and the pseudocyst. The presence of a significant amount of solid material in the pseudocyst is a relative contraindication for endoscopic drainage. Endoscopic ultrasound is a useful adjunct for confirming wall thickness, the nature of the pseudocyst contents and the presence of intervening vascular structures that may give rise to haemorrhagic complications during endoscopic drainage.

Pseudocyst-gastrostomy

This procedure can be performed using either an open or a laparoscopic technique and is suitable for pseudocysts lying behind the stomach. Surgical drainage is to be preferred when the pseudocyst contains a large amount of necrotic material or when previous endoscopic drainage has failed. A longitudinal anterior gastrotomy is performed between stay sutures. Aspiration through the posterior wall of the stomach with a needle and syringe helps to localise the pseudocyst. Following this, deep stay sutures are placed in the posterior stomach wall and an incision is made through the wall (Figure 20.10). As soon as entry into the pseudocyst is achieved, absorbable sutures should be placed encompassing all layers of the stomach and the pseudocyst wall. The pseudocyst-gastrostomy is lengthened, along with the sequential placement of sutures. Any necrotic material within the cyst can be removed through this opening. A nasogastric tube is placed within the stomach. The anterior gastrotomy is closed.

Pseudocyst-jejunostomy Roux-en-Y

This procedure is suitable for pseudocysts with a significant component that would not have adequate dependent drainage into the stomach. A side-to-side pseudocyst-jejunostomy is undertaken using a 60-cm Roux loop.

Pancreatic fistulae and pancreatic ascites

Pancreatic fistulae and ascites occur as a consequence of pancreatic duct disruption. As with pseudocysts, fistulae and ascites arise as a consequence of trauma or acute or chronic pancreatitis and can also follow pancreatic surgery or any operation where the pancreas was inadvertently damaged. The basis for successful management of both conditions is the attainment of effective pancreatic duct drainage using an approach similar to that for the management of pancreatic pseudocysts. For the majority, endoscopic pancreatic duct stenting results in resolution of a pancreatic duct disruption, as long as a stricture does not exist between the site of disruption and the pancreatic stent. In cases where a stricture exists proximal to the site of duct disruption, surgical resection may be required. Effective pancreatic duct drainage may be supplemented by the use of parenteral nutrition, a nil-by-mouth regimen and the prescription of octreotide to reduce pancreatic secretion.

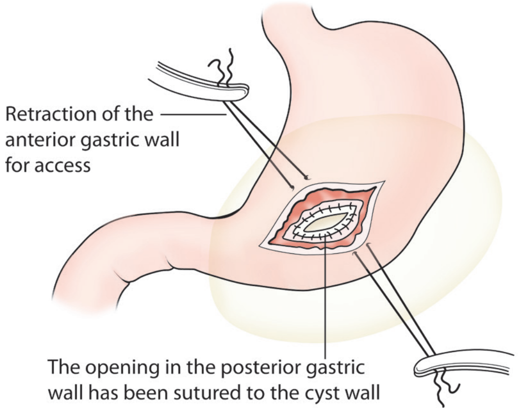
Retraction of the anterior gastric wall for access
The opening in the posterior gastric wall has been sutured to the cyst wall

Figure 20.10 *Pseudocyst-gastrostomy.*

SURGERY OF THE SPLEEN

Anatomy

The spleen lies between the fundus of the stomach and the diaphragm, under cover of the 9th, 10th and 11th ribs, its long axis being in the line of the 10th rib. Normally, the organ lies entirely behind the mid-axillary line and does not project below the costal margin. Its concave medial surface is related to the fundus of the stomach in front and to the upper part of the left kidney behind. Its lower part is related to the splenic flexure of the colon and the phrenicocolic ligament.

Peritoneal connections

The spleen is almost completely invested with peritoneum. At its hilum, it is connected to the upper part of the greater curve of the stomach by the *gastrosplenic omentum* (*ligament*) and to the posterior abdominal wall in front of the left kidney by the *lienorenal ligament*. These ligaments each consist of two layers, one layer being formed by the peritoneum of the lesser sac (Figure 20.11). The tail of the pancreas extends forwards to a variable extent into the lienorenal ligament, and may lie in direct contact with the spleen at the hilum.

Vessels

The splenic vessels are large in proportion to the size of the organ and are very thin walled. The splenic artery arises from the coeliac axis and runs laterally along the upper border of the pancreas until it can turn forwards between the layers of the lienorenal ligament to the splenic hilum. The splenic artery commonly divides into five to eight branches before entering the splenic parenchyma. The *short gastric* and *left gastroepiploic* branches of the splenic artery pass on between the layers of the gastrosplenic ligament to reach the stomach. The splenic vein runs parallel to the splenic artery, but lies below it and behind the pancreas. The inferior mesenteric vein drains into it behind the body of the pancreas, and the splenic vein then joins the superior mesenteric vein behind the neck of the pancreas to form the portal vein.

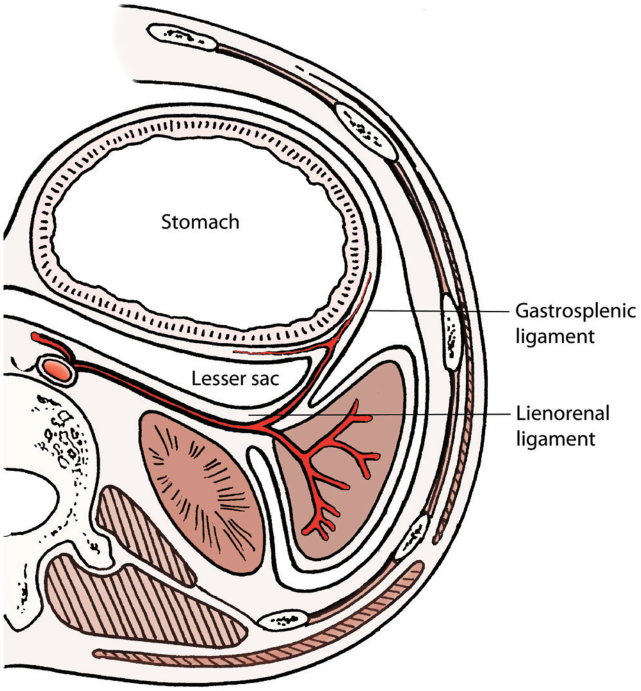

Figure 20.11 *The spleen is anchored at its hilum by two peritoneal folds (ligaments). Large vessels run within these ligaments.*

Splenectomy

The long-term risk of post-splenectomy sepsis was first recognised in young children and only later was it realised that adult patients were at similar, although lesser, risk.[11] This knowledge has encouraged the preservation of injured spleens and also the modification of standard resections for malignancies so that the spleen is only removed when it is necessary on oncological grounds. The dangers from post-splenectomy sepsis have been reduced by increased awareness and the standardisation of immunisations and prophylactic antibiotics.[12]

INDICATIONS

Trauma

Splenic trauma was discussed in Chapter 15, as were a variety of splenorrhaphy techniques that can be used to preserve an injured spleen. These techniques can also be employed for a spleen injured during colonic, gastric or pancreatic surgery. However, the risks of splenic haemorrhage during the post-operative period must be weighed against the disadvantages of its loss, and many surgeons will opt for splenectomy whenever there has been any significant iatrogenic damage.

Spontaneous splenic rupture

This emergency may be associated with a very minor trauma that ruptures an abnormally fragile spleen, or it may be completely spontaneous. The underlying pathology includes malaria, infectious mononucleosis and distal pancreatitis. Splenectomy is usually unavoidable but, as in trauma, functioning intraperitoneal splenunculi may develop from the shattered spleen, leaving the patient with some splenic function.

Malignancy in adjacent organs

The spleen may have to be sacrificed in a radical resection for cancer of the stomach, pancreas or splenic flexure of the colon. However, the spleen was often included in the resected specimen only because it was technically easier to do so. More recently, as the benefits of splenic preservation have become appreciated, some radical excisions have been modified to preserve the spleen where this is oncologically possible (see also Chapters 17 and 18).

Enlarged or overactive spleen

Splenectomy is indicated for a number of haematological disorders and the decision will normally be made by the physician or the haematologist who is managing the underlying condition. Indications include hypersplenism, repeated splenic infarction with recurrent episodes of severe pain and the discomfort and pressure effects of a grossly enlarged spleen. Hypersplenism can occur in a spleen that is only moderately enlarged from another pathology, but the increased rate of destruction of white and red blood cells and platelets becomes the predominant clinical problem. A splenectomy is also sometimes indicated when a spleen is only undertaking its normal physiological role of removing damaged or malformed red blood cells or platelets. This can be counterproductive in conditions such as hereditary spherocytosis and immune thrombocytopaenic purpura. The spleen may also be the site of production of antibody, as in immune thrombocytopaenia, as well as the site of destruction. However, with developments in medical treatment and more awareness of the adverse effects, splenectomy is now seldom advised except for a subgroup of resistant cases. In some countries, splenic complications of sickle cell disease are the commonest indication for splenectomy in childhood.[13]

The aetiology of the giant spleen of tropical splenomegaly is probably multifactorial, with malaria and other infections all implicated. Other causes of giant spleen include myelofibrosis, chronic myeloid leukaemia, schistosomiasis and kala-azar. Earlier medical treatment of the underlying pathology can sometimes prevent this complication, but once giant splenomegaly has developed splenectomy may be unavoidable.

Asymptomatic gallstones should be sought preoperatively in any patient undergoing splenectomy for an underlying haemolytic disorder and if present, a cholecystectomy should be advised.

Miscellaneous

Splenectomy for primary splenic pathology is relatively rare but may be necessary in the management of splenic artery aneurysms, splenic cysts and pyogenic and tuberculous abscesses within the spleen. Splenectomy is no longer part of the staging procedure for lymphomas, but it is occasionally the primary site of the disease and in splenic lymphoma with villous lymphocytes, long-term remission follows splenectomy. Splenectomy is also occassionally indicated for left-sided portal hypertension after a splenic vein thrombosis, in which situation preoperative splenic artery embolisation can make the operation safer.

PREOPERATIVE AND POSTOPERATIVE CONSIDERATIONS

When splenectomy is unavoidable, patients should be immunised against a number of organisms that are implicated in overwhelming post-splenectomy sepsis. Where possible, this should be given at least 2 weeks before surgery. Current UK guidelines recommend immunisation against *Streptococcus pneumoniae* (*Pneumococcus*), *Haemophilus influenza* type b (Hib) and *Neisseria meningitidis* (*Meningococcus*) group C conjugate. Appropriate influenza immunisation should also be given. When an emergency or urgent splenectomy is required, immunisation should be delayed until 2 weeks after surgical intervention in order to ensure the most effective immune response. In addition, lifelong prophylactic antibiotics (oral phenoxymethylpenicillin or erythromycin) are recommended, although the evidence for this is poor and long-term compliance unlikely. Patients should be encouraged to persist for at least a year, ideally wear an identity bracelet stating they have had a splenectomy and be aware of the need for urgent antibiotics should they develop an infection. The reduced resistance to malaria is an additional consideration for people living in endemic areas.

Patients undergoing splenectomy for resistant immune thrombocytopaenic purpura and who are still significantly thrombocytopaenic preoperatively may require perioperative platelet transfusions. Postoperatively, the short-term adverse effects of splenectomy must also be considered. Mortality and morbidity are increased after abdominal surgery in which a splenectomy becomes necessary as an additional procedure. This does not appear to be merely a reflection of a more difficult operation or of more advanced pathology. Infective complications are increased and in addition, the early postoperative rise in platelets can increase thromboembolic complications. The platelet count must be carefully monitored after splenectomy so that appropriate action can be taken. Splenic vein thrombosis is common after splenectomy and the incidence may be higher after a laparoscopic operation. Progression to a portal vein thrombosis is potentially life threatening, but underdiagnosis is inevitable as milder cases will resolve spontaneously.[14] Symptomatic patients present with abdominal pain.

Open splenectomy

A left subcostal or midline incision is usually suitable. A hand is passed over the lateral surface of the spleen, between it and the diaphragm; the organ is lifted forwards and medially and the posterior layer of the lienorenal ligament is divided (Figure 20.12a). This allows the spleen to be delivered up into the wound. Any adhesions to the stomach and colon are normally minimal, but occasionally, there are dense adhesions requiring time and patience to release. Attention is then turned to the gastrosplenic ligament within which run the short gastric and the left gastroepiploic vessels. These vessels are divided between artery forceps and ligated as the lesser sac is entered (Figure 20.12b).

The spleen is still attached by the structures within the lienorenal ligament; the tail of the pancreas must be carefully identified and preserved, and the splenic artery and vein must be isolated, clamped, divided and securely ligated. This dissection can be completed either from in front or from behind. The splenic vessels are very thinwalled and must be

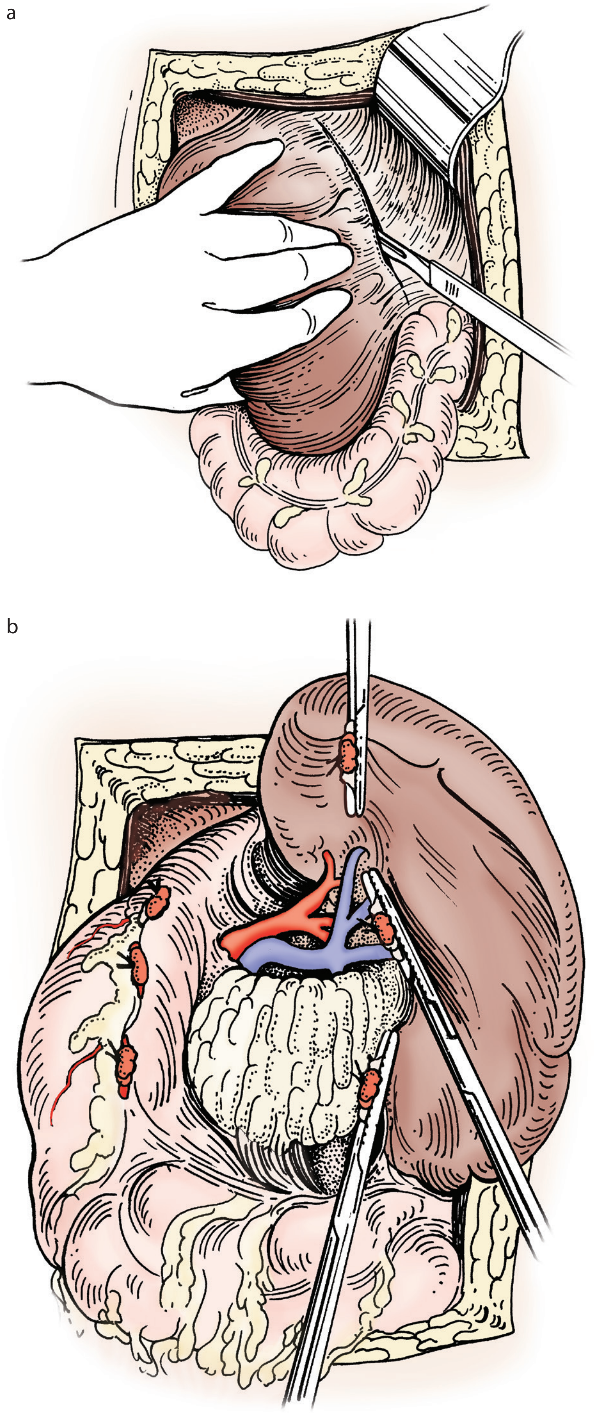

Figure 20.12 *Splenectomy. (a) The peritoneum is incised lateral to the spleen, which can then be delivered up into the wound. (b) The tail of the pancreas is closely related to the splenic hilar vessels and is easily injured by blind application of clamps.*

handled with care. They are often multiple in the splenic hilum and it is then easier to ligate them a few centimetres more proximally. However, this increases the risk of pancreatic injury unless the tail of the pancreas has been accurately delineated and separated from the vessels. The hilar vessels may be clamped and ligated as a single pedicle, but it is recommended that the artery and vein are secured separately. This is probably more secure, but it also avoids the theoretical risk of an arteriovenous fistula. The artery should be clamped before the vein in order to prevent splenic engorgement.

MODIFICATIONS FOR GIANT SPLEENS

A bilateral subcostal incision or the oblique incision, as illustrated in Figure 20.13, may be necessary for access to a giant spleen. If there are no adhesions, the splenectomy can be very straightforward. The splenic ligaments are already stretched and the spleen can be delivered out of the wound. The posterior layer of the lienorenal ligament is divided and the operation proceeds in the standard manner.

Some giant spleens are associated with adhesions, particularly vascular adhesions between the anterior surface of the spleen and the diaphragm, preventing the standard initial mobilisation. The first step in these circumstances is to divide the gastrocolic ligament and the short gastric vessels in order to enter the lesser sac. The splenic artery should then be sought at the upper border of the pancreas and ligated in continuity to reduce vascularity. The adhesions are then divided between the spleen and the stomach, colon and diaphragm so that the spleen can be delivered.

MODIFICATIONS FOR RUPTURED SPLEENS

There may be considerable urgency to control continuing blood loss. Once the posterior leaf of the lienorenal ligament has been divided it is possible to limit haemorrhage by finger compression of the hilar vessels until the dissection has reached a stage where it is possible to clamp the splenic vessels without damage to the tail of the pancreas. (See also Chapter 15.)

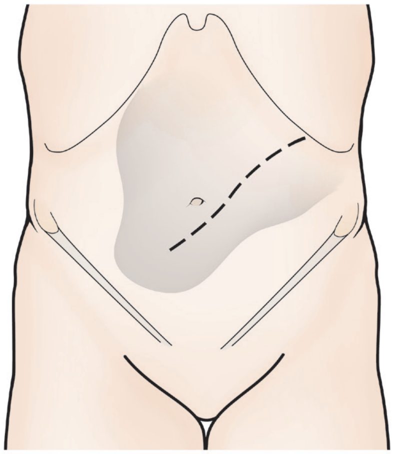

Figure 20.13 *Access for a splenectomy in giant splenomegaly can be difficult. A long oblique incision, which could be extended as a thoracoabdominal incision, has been mostly superseded by a bilateral subcostal approach.*

Laparoscopic splenectomy

This is now the preferred approach for elective splenectomy unless the spleen is grossly enlarged. The patient is placed in a right lateral semidecubitus position. The dissection commences with mobilisation of the splenic flexure so that it can be moved out of the left hypochondrium. The gastrocolic ligament and the short gastric vessels are then divided first. If the main splenic artery can be isolated at this stage above the tail of the pancreas, a ligature in continuity will reduce the vascularity of the remaining dissection. The posterior leaf of the lienorenal ligament is then divided, although it may be better to leave its superior extremity to stabilise the spleen until after the division of the hilar vessels. Clips, ties, vascular staples or Harmonic® coagulation can then be used to secure the short gastric vessels, but a vascular stapling device is recommended for the splenic vessels in the hilum. Similar caution to that needed in open splenectomy must be exercised to avoid inclusion of the pancreatic tail. The spleen can be macerated within a waterproof retrieval bag and delivered through a port site.

SURGERY OF THE ADRENAL GLANDS

Anatomy

The adrenal glands lie over the upper pole of each kidney, where they are embedded in fat and enclosed within the renal fascia. The glands lie superomedial to the kidneys, with the diaphragm posteriorly. The right gland, which is triangular in outline, is in contact anteromedially with the vena cava and anterolaterally with the liver. The left gland, which is more semilunar in outline, extends further down the medial border of the kidney towards the hilum. Its anterior surface is covered by the peritoneum of the posterior wall of the lesser sac, and below it is closely applied to the pancreas and splenic vessels. The arterial supply of the glands is from multiple variable small arteries, which are of little concern during surgery. In contrast, the venous drainage is usually by one large vein, and the safe dissection and ligation of this vein can be the main technical challenge of an adrenalectomy. The right adrenal vein is very short; it leaves the upper part of the anteromedial surface and drains directly into the vena cava (Figure 20.14a). The left adrenal vein is longer; it leaves the anterior surface of the gland and runs downwards and medially to drain into the left renal vein (Figure 20.14b).

Adrenalectomy

INDICATIONS

Hormone-producing tumours

Hormone-producing tumours may be either benign or malignant and may arise from the adrenal cortex or from the medulla. The tumours are often small, but sometimes they are multifocal and bilateral. Presentation with a hormone-producing tumour is with a recognisable clinical syndrome, which is then confirmed biochemically. Imaging then shows the position of the tumour and either confirms or excludes multifocal lesions. Adrenalectomy is the treatment of choice for hormone-producing tumours and the decision to operate is taken after multidisciplinary discussion with endocrinologists and radiologists. The adrenal cortical tumours include those that cause Cushing's syndrome and Conn's syndrome and the rarer tumours that can cause virilisation or feminisation. The pharmacologically active tumour of the adrenal medulla is the *phaeochromocytoma*. Patients with some variants of familial endocrine neoplasia (MEN IIa and IIb) have such a high risk of developing phaeochromocytoma that they are screened regularly. It is this group of patients that is most likely to develop bilateral tumours.

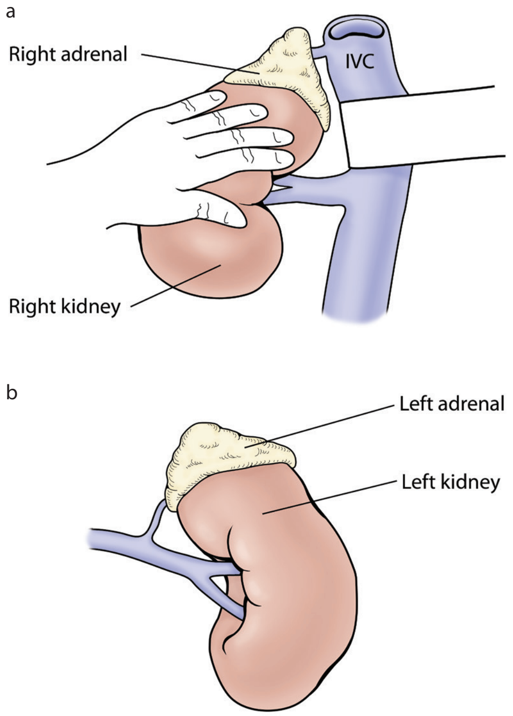

Figure 20.14 *Adrenalectomy. (a) The right adrenal gland lies against the inferior vena cava (IVC). The short right adrenal vein is displayed by gentle lateral retraction of the kidney and medial retraction of the IVC. (b) The left adrenal vein is more easily visualised as it runs a longer course, obliquely down to the left renal vein.*

Non-hormone-producing tumours

Tumours that do not produce hormones may grow to a large size and only present when they cause compression or invasion of adjacent structures. They can arise from either the cortex or the medulla. *Ganglioneuromas* arise in neural crest cells and a small percentage of these tumours are from the adrenal medulla. The tumours are relatively benign and are often very large at presentation. The more aggressive *neuroblastoma* of infancy and early childhood more often arises from the adrenal medulla than from other neural crest cells.

It also grows to a large size and an abdominal mass is the most common presentation. Unfortunately, 70 per cent of these lesions will already have metastasised before diagnosis. Adrenalectomy is indicated if these tumours are still technically resectable and there are no metastases.

Management dilemmas were posed by the introduction of high-quality abdominal imaging, as unrelated pathology of doubtful significance was also discovered. Small adrenal tumours were detected and, as the malignant potential of these was unknown, initially there was debate as to whether they should be ignored, watched or excised. Adrenalectomy is now advised for lesions over 3 cm and smaller lesions are monitored with serial imaging.

Bilateral adrenal hyperplasia

Pituitary-dependent Cushing's disease is now seldom treated by bilateral adrenalectomy. Rather, the pituitary adenoma is treated by pituitary ablation or radiotherapy. Alternatively, cortisol secretion is blocked pharmacologically. Bilateral adrenalectomy is reserved for cases where these interventions have failed. Similarly, when treatment aimed at primary control of ectopic adrenocorticotropic hormone-secreting tumours has failed, bilateral adrenalectomy can provide useful palliation of the symptoms of cortisol excess. Bilateral adrenalectomy is also occasionally undertaken for the rarer autonomous adrenal hyperplasia.

Adrenal metastases

Adrenalectomy for isolated metastatic disease within an adrenal gland is increasingly considered within a multidisciplinary setting.

MEDICAL AND ANAESTHETIC CONSIDERATIONS

Surgery on patients with hormone-producing tumours is complicated by the biochemical effects of the excess circulating hormones. Haemodynamic instability from high levels of catecholamines can be particularly challenging in patients with phaeochromocytoma. However, preoperative and perioperative pharmacological blockade of the excess circulating hormone can now make this surgery relatively uneventful. The patient is usually referred to the surgeon after full investigation and treatment by the endocrinologist, and the anaesthetist is fully prepared for any unexpected instability. Nowadays, the danger is when a surgeon unexpectedly encounters an adrenal lump. The anaesthetist should be warned prior to any dissection and extreme gentleness is important to avoid a sudden bolus release of pharmacologically active secretions into the circulation.

Patients who have a bilateral adrenalectomy require lifetime cortisol and adrenocorticoid replacement therapy.

Surgical approaches to the adrenal glands

The adrenal glands can be approached either transabdominally or from the loin. The deep-seated position of these small glands has always required a disproportionately large incision for access and, as a consequence in recent years, an increasing proportion of adrenalectomies have been performed laparoscopically by a variety of techniques.[15] Initially, open surgery was reserved for large tumours and malignant tumours, but now many of these have also proved suitable for a laparoscopic approach in specialised centres.[16] The loin and posterior approaches, whether open or laparoscopic, provide limited access for the excision of a large tumour.

OPEN ANTERIOR APPROACH

This was the standard approach for the once common bilateral adrenalectomy for metastatic breast cancer, as it gives good access to both adrenal glands. In addition, before accurate preoperative imaging was available, bilateral surgical exploration was often necessary for hormone-producing tumours so that both glands could be inspected and palpated. A transverse upper abdominal incision is satisfactory; alternatively, it can be a curved incision, convex upwards. A subcostal incision is suitable for a unilateral adrenalectomy.

Right adrenal gland

The right adrenal gland is exposed by a peritoneal incision between the upper pole of the kidney and the lateral edge of the inferior vena cava (IVC). Usually, the right adrenal gland lies just cranial to the duodenum, but it can be overlain by both the duodenum and the hepatic flexure of the colon. When necessary, the duodenum and hepatic flexure are mobilised and then lifted forwards to expose the kidney and adrenal gland (see Chapter 14 and Figure 14.2). The liver is held up with a retractor and the right lobe mobilised by incising the peritoneal reflection from the hepatorenal fossa. The kidney is drawn laterally and downwards to display the plane between the IVC and the adrenal gland. Careful dissection in this plane with medial retraction of the IVC allows identification of the adrenal vein (see Figure 20.14a). This is ligated and divided. Great care must be exercised as the vein is often less than 5 mm in length and major venous bleeding ensues if the vein is avulsed from the IVC. If this should happen, the management is similar to that when a ligature slips on the renal vein, and is discussed in more detail in Chapter 26 (p. 487). The multiple small adrenal arteries can be coagulated with diathermy as the mobilisation and removal of the gland are completed.

Left adrenal gland

The left adrenal gland lies behind the pancreas. The parietal peritoneum can be incised at the lower border of the pancreas after an incision has been made into the lesser sac. The pancreas and splenic vein are then retracted upwards. Alternatively, an incision lateral to the spleen allows the spleen, splenic vessels and pancreatic tail to be lifted forwards and retracted medially to expose the left kidney and adrenal gland. Although these approaches are more difficult than the exposure on the right, ligation of the left adrenal vein is less hazardous, as it is usually easily visualised and of a length that can be ligated without difficulty.

LAPAROSCOPIC TRANSPERITONEAL APPROACH

Although this approach is possible with the patient supine, it is usually better to place the patient in the lateral decubitus position, head up and the table broken to open the renal angle, so that gravity acts as a natural ‘retractor’. The operation is essentially the same as in the anterior open approach.

Right adrenal gland

Three or four right subcostal ports are commonly used. The right triangular ligament is divided and the liver retracted medially to expose the kidney and IVC. A vertical incision medial to the upper pole of the kidney exposes the gland.

Left adrenal gland

Three left subcostal ports usually suffice. The splenic flexure is mobilised and the lienorenal ligament divided. The spleen then displaces forwards under gravity to expose the kidney and adrenal gland.

OPEN LOIN AND POSTERIOR APPROACHES

Any of the loin approaches for renal surgery described in Chapters 13 and 26 can be used. The lateral decubitus position is used for a loin incision and the prone jack-knife position for the posterior lumbotomy incision (see Figure 13.14, p. 216). Posterior incisions have an advantage if both adrenal glands must be explored, as the patient does not need to be turned.

LAPAROSCOPIC LOIN AND POSTERIOR APPROACHES

The patient is positioned in the lateral decubitus or the prone jack-knife position as for the open retroperitoneal approach. The first port is placed under direct vision into the retroperitoneum and a retroperitoneal space is created by balloon insufflation. Completeness of adrenal gland excision can be a particular problem with the posterior retroperitoneal approach. Recurrent Cushing’s syndrome has been reported in up to 20 per cent of cases.[17]

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21

SURGERY OF THE LIVER

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ANATOMY AND PHYSIOLOGY

Anatomy

The surface anatomy of the liver, which presents itself to the surgeon at laparotomy, bears little resemblance to the complex internal anatomy. The appreciation of this internal anatomy has been one of the major factors in the development of complex liver surgery.[1]

SURFACE ANATOMY

The liver lies immediately below, and in contact with, the diaphragm. It is located mainly beneath the right dome of the diaphragm, where it fills the whole of the protected area within the costal margin, but it also extends across the midline as a progressively thinner left lobe. The liver is clothed in adherent peritoneum except in the bare area posteriorly, the gallbladder fossa and at the attachment of peritoneal folds. These folds are the most obvious surface features. The *falciform ligament* is a peritoneal fold between the anterosuperior surface of the liver and the anterior abdominal wall. Its free inferior edge contains the *ligamentum teres*, which is the obliterated left umbilical vein. The ligamentum teres is sometimes referred to as the umbilical ligament. The falciform ligament divides the liver into right and left 'lobes'. Much confusion has arisen from this nomenclature, as these lobes are not synonymous with the right and left halves of the liver as defined by the internal anatomy. A left lobectomy therefore describes the excision of only the liver to the left of the falciform ligament, whereas a left hepatectomy, based on the internal anatomy, describes the excision of just under half of the liver (Figure 21.1). At the posterior extremity of the falciform ligament, two further folds extend laterally – the left triangular ligament and the coronary ligament – which attach the liver to the diaphragm. The left triangular ligament is narrow, but the leaves of peritoneum forming the coronary ligament are widely separated and encompass the bare area of the liver. Laterally, the coronary ligament narrows to end as the right triangular ligament (Figure 21.2). The surgical importance of these ligaments is simply the need to divide them in order to mobilise the liver and improve access during resection.

The *porta hepatis* is a transverse cleft far back on the inferior surface of the right lobe. It transmits the portal vein, the hepatic artery and the hepatic ducts. The lesser omentum is a

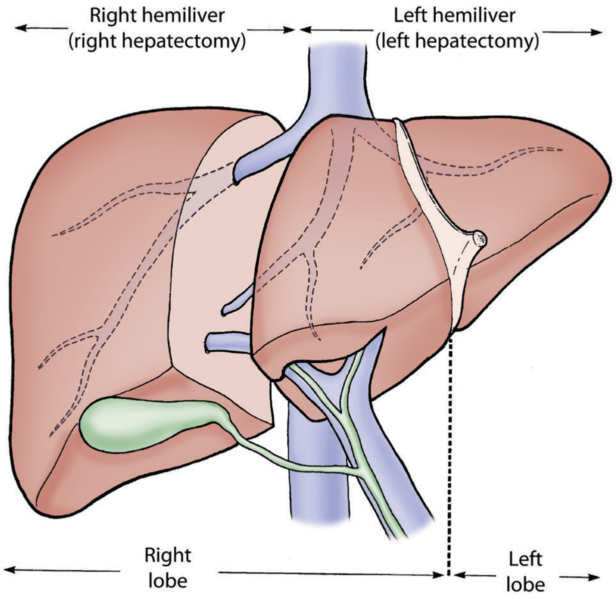

Figure 21.1 *The falciform ligament divides the liver into two lobes, but this division does not represent the plane between the two halves of the liver.*

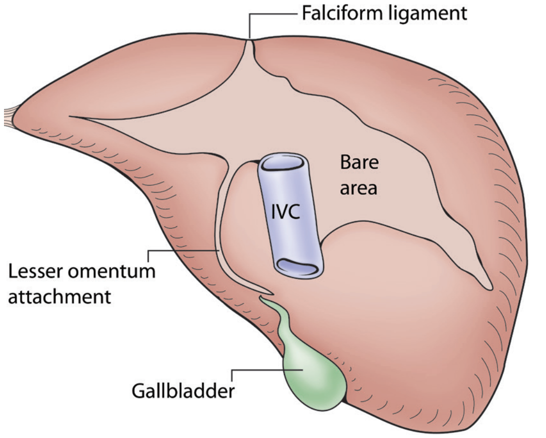

Figure 21.2 *The bare area of the liver viewed from behind. After full mobilisation the liver is only fixed by the hepatic veins draining into the inferior vena cava (IVC) and the attachment of the lesser omentum around the structures of the porta hepatis.*

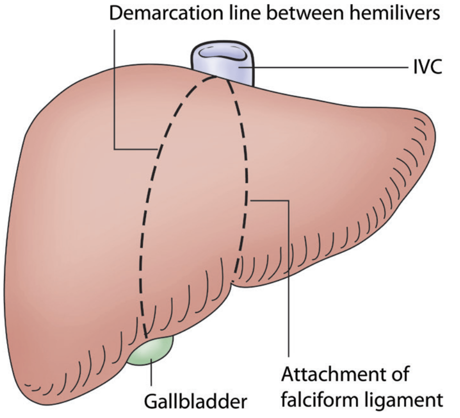
Demarcation line between hemilivers
IVC
Gallbladder
Attachment of falciform ligament

Figure 21.3 *The plane between the right and left halves of the liver lies at around 20 to 30 degrees from the vertical, and extends from the gallbladder fossa anteriorly to the insertion of the middle hepatic vein into the inferior ven cava (IVC) posteriorly.*

peritoneal fold that is attached to the liver around the porta hepatis. From there it stretches to the lesser curve of the stomach and the first part of the duodenum, with the hepatic artery, the portal vein and the bile ducts lying in its right free border. The common bile duct lies anteriorly and to the right and the hepatic artery lies anteriorly and to the left. The portal vein lies behind. This free border forms the anterior boundary of the epiploic foramen into the lesser sac. The only other obvious surface landmark on the liver is the gallbladder, which lies directly against the inferior surface of the right lobe and is covered on its inferior surface, and also on a variable percentage of its circumference, by the peritoneum of the liver. The fundus of the gallbladder is the anterior landmark for the division between the two halves of the liver as defined by the internal anatomy. The posterior landmark between the two hemilivers is the insertion of the middle hepatic vein into the inferior vena cava (IVC), and the line between lies at around 20–30 degrees from the vertical (Figure 21.3). The IVC is closely applied to the posterior surface of the liver. Frequently, it is partially covered by the peritoneum of the posterior wall of the lesser sac and it is also partially in direct contact with, or even buried within, the bare area of the liver. The hepatic veins drain directly into the vena cava.

SEGMENTAL ANATOMY

The hepatic artery and the portal vein divide into left and right branches in the porta hepatis, just outside the liver substance. At the same level the right and left hepatic ducts converge to form the common hepatic duct. The right portal structures run a near-vertical course in the hilum and enter the liver substance within a few millimetres. The left hilar structures run a longer and more horizontal course before entering the liver parenchyma, and they then turn to follow a more vertical course. The three portal structures are surrounded by a fibrous sheath, and this sheath also splits to enclose the diverging right and left structures as they enter the right and left halves of the liver, respectively. This extension of the vascular biliary fibrous sheaths continues to surround the second and third divisions of the portal triad, which finally terminate in the separate functional units, or segments. The second-order divisions divide the liver into four distinct parts or sections – a medial and lateral section on the left, and an anterior and posterior section on the right. The third-order division divides the liver into eight segments (Figure 21.4). This anatomical arrangement allows the main bulk of the liver to be considered as either two halves, four sections or eight segments, each based on a portal pedicle, when a resection is planned. Further divisions of the portal triad allow some segments to be considered as separate subsegments. For example, segment 4 can be divided into segments 4a and 4b and the caudate lobe (segment 1) may be considered as two further segments – a left half (segment 1L) and a right half (segment 1R). Segments 2 and 3 (lateral section) lie to the left of the falciform ligament. Segments 4a and 4b (medial section) are to the right of the ligament and up to the main plane of a line from the gallbladder fossa to the insertion of the middle hepatic vein. Segments 5 and 8 (anterior section) are lateral to the main plane and occupy roughly half of the right hemiliver. Segment 5 lies immediately next to the gallbladder. The posterior section of the right half contains segments 6 and 7. The relative size of all segments varies between individuals.

Whereas the portal pedicles run within the segments, the hepatic veins run mainly between segments and converge posteriorly to drain into the IVC (Figure 21.4). The right hepatic vein drains most of segments 6 and 7 and part of segments 5 and 8. A variable posteroinferior vein drains from segment 6 directly into the vena cava, and there are also multiple small veins draining the right liver adjacent to the IVC directly into it. The middle hepatic vein lies in the plane between the two halves of the liver and drains segments 4, 5 and 8, before usually joining the left hepatic vein just before it in turn drains into the vena cava. The left

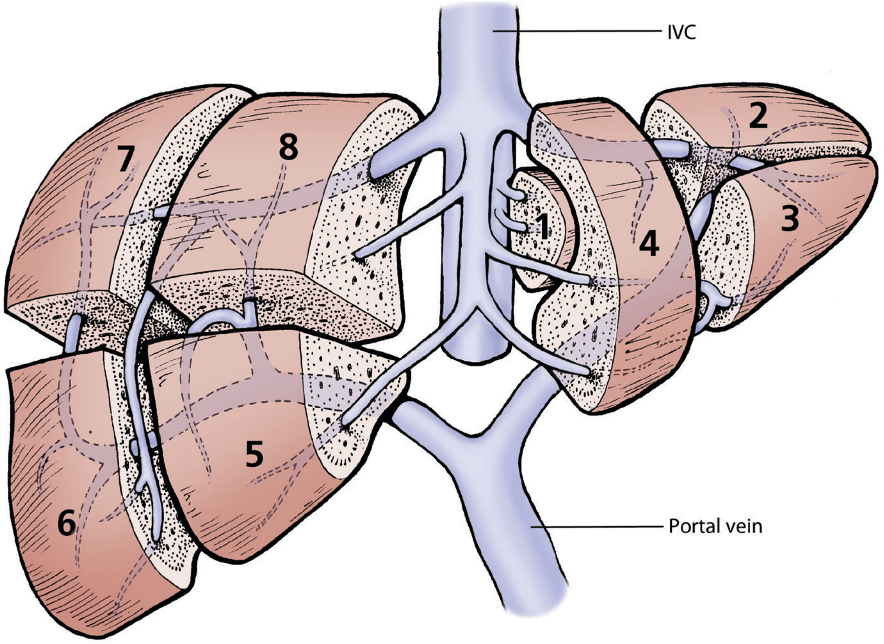

Figure 21.4 *Diagrammatic representation of the liver segments as viewed from the parietal surface (after Couinaud). The portal vein is the only structure in the portal triad that has been shown in the drawing.*

hepatic vein drains segments 2 and 3. There is usually a small umbilical vein, running in a plane deep to the umbilical ligament, which may be useful in maintaining venous drainage of segment 4b in cases where the middle hepatic vein is taken. The caudate lobe drains directly into the vena cava, via one or more separate veins. The details of the biliary, portal, hepatic arterial and venous anatomy, and the common variants that can produce challenges to the surgeon, are discussed further in the sections on individual resections.

Physiology

The major role of the liver as a metabolic organ must not be forgotten, despite the challenges of its anatomy. Its blood supply is 25 per cent of the resting cardiac output, and its importance as a processor of the nutrients absorbed from the gastrointestinal tract is emphasised by the fact that 75 per cent of its blood supply is from the portal vein. Glycogen is stored in the liver, proteins and peptides are synthesised, and waste products are broken down to be eliminated in the bile or excreted by the kidneys. The liver has great powers of regeneration. This was recognised in ancient Greek mythology in the Prometheus legend. Prometheus was tortured by a vulture that, each day, ate a proportion of his liver, which then regenerated in time for the next attack. As much as 60–70 per cent of a healthy liver can be removed without precipitating liver failure. However, the situation is not so favourable if the liver is already permanently damaged by cirrhosis or temporarily impaired by biliary obstruction or cytotoxic chemotherapy.

PREOPERATIVE INVESTIGATIONS

Imaging

Until the advent of CT and ultrasound scans, contrast studies of the intrahepatic bile ducts were the only useful preoperative anatomical imaging available to the surgeon. No information could be obtained about lesions within the liver parenchyma, except where there was distortion of a main duct, and no information was available on the relationship of a mass to major intrahepatic vessels. An unenhanced CT scan provided only limited information, but the addition of contrast and careful timing of images became increasingly sophisticated and CT is now the mainstay of hepatic imaging. In recent years, liver MRI scans, using liver-specific contrast agents, have become favoured within specialist hepatobiliary units. Both the triple phase-contrast CT and MRI with liver-specific contrast agents have the ability to identify accurately abnormal lesions in the liver and also to delineate the relationship of such lesions to the intrahepatic anatomy. MRI has greater ability to differentiate lesions and thereby helps to distinguish between those that are benign and those that are malignant.

Physiology

The preoperative preparation of a patient for surgery is discussed in Appendix I. When planning any liver surgery, it is important to know whether the essential metabolic functions of the liver are impaired by the underlying pathology. Particular care in assessment is important in patients with cirrhosis and those with obstructive jaundice (see also Chapter 19). It is important to consider the reserve physiological capacity of the liver and the regeneration potential of the remnant when a major resection is planned, otherwise an apparently successful resection may be followed by fatal liver failure. Temporary liver decompensation frequently occurs after major liver resections, but improves as liver regeneration progresses. Biochemical measurements can provide some indication of both the physiological reserve of the liver and of its regenerative capacity, but are not always an accurate prediction of the metabolic complications of the postoperative period.

Histological proof

There is frequently doubt over the pathology of lesions within the liver, especially when they are small and do not show classic features on imaging. However, biopsy should always be avoided if there is the potential for a curative resection. All techniques, whether open, laparoscopic or image-guided needle biopsies, spill malignant cells into the peritoneal cavity. A percutaneous needle biopsy has the additional capacity to implant malignant cells along the needle track, with resultant abdominal wall or diaphragmatic secondary deposits.[2,3] Small lesions in the liver should be monitored by serial scans as an increase in size not only suggests malignancy, but slightly larger lesions are also easier to differentiate on imaging modalities. Occasionally, a surgeon must decide to proceed to a liver resection when doubt still remains. Both the surgeon and the patient must be prepared to accept that the surgery may, in retrospect, prove to have been unnecessary in that the resected abnormality is histologically benign, although with meticulous preoperative assessment this can be kept to less than 1%.[3]

GENERAL LIVER TECHNIQUES

Historical perspective on liver surgery

Until the closing decades of the twentieth century, liver surgery carried a daunting mortality and morbidity. This was mainly related to major intraoperative haemorrhage. Attempts to reduce blood loss concentrated more on speed than on precision. The need to work very quickly in an operative field where visibility was obscured by bleeding was probably at least in part responsible for some of the other complications that were more common in this era. Precision has proved more important than speed, but this precision has only become possible with advances in both knowledge and technology. The anaesthetist can now provide optimum intraoperative physiological conditions for the surgeon. In turn, the surgeon must be armed with knowledge of the segmental anatomy of the liver and discern additional information on any anatomical anomalies, using both preoperative and intraoperative imaging. With these two criteria met, combined with the improvements in surgical technique that became possible with technological advances, it was finally practical to operate on the liver with minimal blood loss and low mortality and morbidity.[4]

Anaesthesia

The tendency for bleeding during transection of the liver is related to the level of the central venous pressure (CVP). When the CVP is below 6 mmHg, bleeding can be minimal, whereas if it is above 13 mmHg, bleeding will almost certainly be troublesome, even with the most careful surgical technique. The anaesthetist should therefore attempt to keep the CVP as low as possible during liver surgery by restricting fluids and administering a glyceryl trinitrate infusion.[4]

Access

A long transverse or oblique subcostal incision with the patient placed supine or partially lateral has replaced the traditional thoracoabdominal incisions. The past decade has seen the length of the incision gradually shortened, which is associated with a reduction of the mean length of stay.

Mobilisation of the liver is essential for adequate surgical access, especially when the pathology is in the posterosuperior portion of the right lobe. Fixed retraction of the costal margin, as illustrated in Figure 14.1a (p. 228), is helpful. The falciform and triangular ligaments are divided. Small vessels in the free edge of the falciform ligament will need to be secured by ligation of the ligamentum teres. As the dissection to complete the division of the three ligaments converges posteriorly, the vena cava and hepatic veins can be damaged (see Figure 21.2). Accidental division of smaller phrenic veins can also cause troublesome bleeding. The left half of the lesser omentum is divided and the lesser sac entered. After full mobilisation, the liver is attached only by the hepatic veins to the vena cava and by the structures in the porta hepatis. It can be rotated out from its normal anatomical position into the wound and packs placed behind it to maintain its position. These packs have the additional benefit of holding the liver in a position such that the anatomical plane between the two halves of the liver is vertical rather than oblique. A vertical plane is easier for the surgeon to identify and follow.

Laparoscopic liver surgery has become an alternative approach in recent years. In some Hepato-Pancreatico-Biliary (HPB) centres it is routine for smaller resections such as segmentectomy 2/3. Even though hemihepatectomies have been performed laparoscopically, it is by no means routine as it requires extensive experience of both laparoscopic and hepatobiliary techniques.[5]

Intraoperative ultrasound

Intraoperative ultrasound is now a standard part of many liver resections. It can be used to identify intrahepatic lesions that have not been visualised on preoperative imaging, but with improvement in imaging this is becoming of lesser value. Of greater value is the ability to map the segmental anatomy by the identification of intrahepatic structures.

Liver dissection

A liver incision bleeds profusely from multiple small vessels in the liver parenchyma. Bleeding can be reduced by lowering the CVP and by temporary occlusion of the inflow to the liver with a Pringle clamp, as outlined below. It can also be reduced by following the planes between the two halves of the liver or the planes between liver segments. This can be done more accurately if the inflow to the area to be removed has been previously ligated and the surgeon is able to follow a line of demarcation. In addition, advances in technological equipment allow more precise dissection.

THE PRINGLE MANOEUVRE

The Pringle manoeuvre has stood the test of time since its first description in 1908.[6] It consists of placement of a soft occlusion (non-crushing) clamp or occlusion tape across the free edge of the lesser omentum, thus occluding the inflow to the liver from both the hepatic artery and the portal vein. (Partial inflow occlusion – possible with three light ‘clicks’ on the clamp – may reduce the risk of thrombosis of the hepatic artery or portal vein.) Assessment of an injury or dissection for a liver resection can then proceed with greatly reduced bleeding. If the occlusion does not arrest arterial inflow into the liver, an aberrant hepatic artery arising from the left gastric artery should be sought in the lesser omentum, and an additional soft clamp placed across it. The ‘safe’ time for such occlusion is difficult to quantify. During elective resection of a segment of otherwise healthy liver, total occlusion for as long as 90 minutes may be tolerated without detriment. The physiological reserve of the remnant and the ability to regenerate may, however, be compromised by as little as 20 minutes of occlusion when a more major resection is undertaken in a liver that is already compromised by cirrhosis or other pathology. There is evidence that longer times can be tolerated if a short period of occlusion is undertaken initially, and a variety of occlusion regimes have been instituted. Transection of the liver with removal of the clamp and reperfusion of the liver for about 5 minutes after each 20-minute period of occlusion is one that can be recommended. The length of occlusion is reduced to 10 minutes if the liver is compromised or cirrhotic.

EARLY LIGATION OF INFLOW

Early ligation of inflow has long been practised in right and left hepatectomies where the hepatic artery and portal vein to the hemiliver to be excised is ligated in the porta hepatis before division of the parenchyma is commenced. The advantage of this approach is that the line of demarcation becomes apparent between well-perfused and ischaemic liver. This underlines the fact that there is little collateral flow between the two halves of the liver and that a surgical plane between the two halves should be relatively bloodless. The surgeon can then follow the plane accurately during dissection. The realisation that the perfusion of each liver segment is equally discrete should, in theory, allow a similar technique to be employed for segmentectomy, but it is often not possible to isolate the inflow vessels for occlusion until some parenchymal dissection has been undertaken.

CAVITRON ULTRASONIC SURGICAL ASPIRATOR

The Cavitron ultrasonic surgical aspirator (CUSA) has become a standard instrument for optimal division of liver parenchyma. Traditionally, the liver parenchyma was divided by ‘finger fraction’; this disrupted the liver cells and exposed larger vessels intact, which could then be ligated and divided. However, this method is imprecise, smaller vessels are disrupted and bleeding is still profuse. The CUSA divides the liver following a similar principle, but is much more delicate and precise. The liver cells are vaporised by the sound waves and aspirated, while all fine tubular structures, including small vessels and bile duct radicles, are skeletonised and can be seen straddling the most recent parenchymal division. However, some surgeons will not have access to this technology and the crush-clamp technique has proved comparable in recent trials.[7]

LIGATION OF VESSELS AND BILE DUCTS WITHIN THE LIVER

Structures of less than 1 mm in diameter, skeletonised by the CUSA, can be secured by diathermy. Any larger structures should be ligated with fine absorbable material (e.g. 3/0 Vicryl®) and divided between the ligatures. Larger vessels and ducts to segments or subsegments of the liver may also appear in the line of division. As a general rule, any structure of a size that merits a name should have two ligatures on the end that is to be left inside the patient.

HEPATIC VEIN DIVISION

Simple ligation is usually contraindicated, as the veins are so short and wide that a ligature would be insecure. A transfixion ligation, although theoretically more secure, is also unsatisfactory as it inevitably bunches and distorts the wall of the vena cava. The only satisfactory method, other than a stapled closure, is a sutured closure. The vein is divided between clamps and oversewn with a fine Prolene® vascular suture. A monofilament suture, which slides through tissue without tearing, is essential, as all of the continuous suture must be in place before the clamp is removed and the suture tightened (Figure 21.5). If the clamp should slip during this manoeuvre, haemorrhage from the vena cava can be torrential. Air embolism is also a potential danger, especially in a patient with a low CVP. Techniques for controlling and

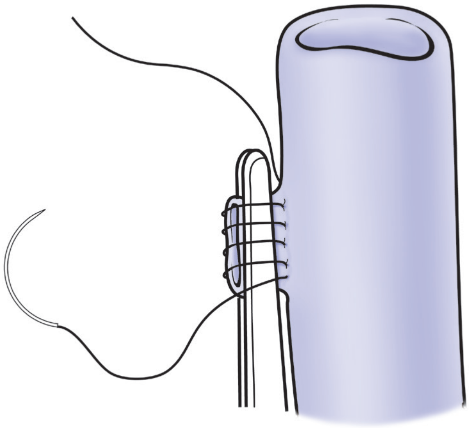

Figure 21.5 *Sutured closure of a short, wide hepatic vein.*

suturing an inadvertent venotomy in the IVC are described in Chapter 26 (p. 487) in relation to a similar complication that can arise during nephrectomy. A stay suture applied to both the superior and inferior borders of any large vein prior to division between clamps is recommended.

Endo GIAs

Endo GIAs™ are small cutting linear stapling devices that have revolutionised the difficulties in control and division of hepatic veins. These thin-walled veins draining directly into the vena cava have always been technically challenging, not least because of restricted access.

ARGON BEAM COAGULATION

Argon beam coagulation is a spray diathermy that produces superficial coagulation to a depth of only a few millimetres. It has proved extremely valuable in arresting the surface ooze from a large raw area and has found one of its main applications in liver surgery.

HAEMOSTATIC MATERIALS

Absorbable, pharmacologically active materials that enhance clotting are particularly helpful when there is persistent low-volume ooze from the large raw surface of a major resection. There is a wide range of proprietary products available, including sheets and teased-out fibres, which can be laid against the surface, and 'tissue glue' or fibrin, which can be spread or sprayed onto a bleeding area.

DRAINS

After a liver resection, drains are recommended as the best method of both detecting and treating an early bile leak. An early leak represents a technical failure in identifying or securing a bile duct radicle. If there is no leak, a drain should usually be removed within 72 hours as it can cause trauma to the tissues. Late bile leaks, which are associated with tissue sloughing, occur at about 10–14 days and long after any drain has been removed. Excessive bleeding during the immediate postoperative period may also be detected earlier if there is a drain in place.

Specialisation

It should now be possible to perform liver surgery with a low mortality and morbidity despite the increasing complexity of the resections undertaken.[8] This is, however, only possible in centres specialising in liver surgery. Such centres now have series of over 2,000 liver resections and are able to report mortalities of under 2 per cent with median blood losses as low as 340 ml. In the developed world, transfer to specialist centres should be possible for all elective cases and for most patients with liver trauma who need a resection. There are, however, surgeons practising in remote hospitals in countries with restricted health budgets. If referral to a major centre is not possible, the general surgeon should be very wary of embarking on any but the most minor elective liver surgery. Despite good surgical technique and attention to detail, the morbidity and mortality from major liver surgery will remain unacceptably high in suboptimal surgical circumstances.

LIVER RESECTION

Anatomically-based partial hepatectomies involve the removal of one or more segments of liver parenchyma by isolation and division of the relevant portal pedicle and hepatic veins. They are employed for most major resections, whereas non-anatomically-based resections still have a place for some small tumours.

Small non-anatomical resections

Small non-anatomical resections are not based on the intrahepatic anatomy, but are suitable for the removal of small, peripherally situated tumours. Traditionally, these excisions were wedge-shaped, to allow a sutured closure for haemostasis (as illustrated in Figure 15.3, p. 250). They were therefore often described as 'wedge resections'. Today, non-anatomical resections are more frequently performed as a circular excision, which may be shallow and saucer-shaped, or deeply indented from the removal of half a sphere of tissue to include a lesion further from the surface. As the excision does not follow the anatomical boundaries of vascular inflow, no preliminary ligation of inflow vessels to reduce haemorrhage is possible. Instead, the surgeon must rely on CUSA dissection and individual ligation of parenchymal vessels and bile radicles. The liver wound is left open. Care must be taken to avoid a non-radical excision with this technique. It is well-documented that the surgeon may underestimate the extent of resection required and hence get a 'positive' or involved margin.

Right hepatectomy

This excision is along the anatomical plane between the two halves of the liver. The operation commences with division of the falciform, triangular and coronary ligaments. The assistant rotates the liver to the left and the retrohepatic

IVC is cleared. Care must be taken to separate the right adrenal gland from the bare area of liver. At this stage it may be convenient to secure the small hepatic veins draining directly into the IVC from the back of the right liver, but the main right hepatic vein should be left until the end of the operation to prevent venous engorgement. However, a band of fibrous tissue – the hepatovenacaval ligament – can be divided. This structure is said to be bloodless, but it occasionally harbours a significant venous tributary, which must be secured. The liver is then returned to a more neutral position, but with packs behind the right liver to lift it forwards into the wound. In this way the packs rotate the right lobe of the liver so that the plane between the two halves is vertical. A cholecystectomy is then performed. The anterior leaf of peritoneum of the lesser omentum is then divided in the porta hepatis, thus exposing the right hepatic duct, the right branch of the portal vein and the right hepatic artery. The right hepatic artery is easily identified and then suture-ligated and divided. This exposes the right branch of the portal vein. It is safer to secure this vessel either with an Endo GIA™ or a sutured closure rather than with a simple ligature. A small caudate branch to the right must also usually be divided. Division of the right hepatic artery and the right portal vein produces a line of demarcation between the two halves of the liver. While the right duct can be divided at this stage, it may be safer to take the duct later, during the parenchymal transection, to avoid inadvertent damage to the left duct. An alternative strategy is only to occlude the right hilar vessels with a soft clamp at the initial dissection in the porta hepatis. This will produce the same line of demarcation without the finality of a division, and all the structures of the portal triad can then be divided more distally at a later stage in the dissection, as illustrated in Figure 21.6. This may prove a safer option, especially if there are anatomical anomalies.

Transection of the liver parenchyma is then commenced, as described above. This transection should be in the ischaemic half of the liver, approximately 5 mm from the line of demarcation. However, the line of transection will often have to encroach into the left hemiliver to ensure radical excision of more centrally based tumours. If a Pringle clamp is to be used, the surgeon should mark the intended line for the transection on the capsule of the liver with diathermy before the clamp is applied, as demarcation will no longer be obvious once an occlusion clamp is across all structures at the porta hepatis. The middle hepatic vein lies in the plane of dissection (see Figure 21.4) and is best preserved if possible, as it can provide venous drainage of part of the left liver. However, several veins drain into it from the right liver and cross the plane of the dissection. Each of these must be ligated and divided. The larger right hepatic vein, which drains directly into the IVC, requires meticulous division and suturing. Alternatively, the vein may be divided with a haemostatic stapling device. In addition, several small veins draining directly into the vena cava must be secured, if this has not been done at an earlier stage. In 25 per cent of people there is also a larger posteroinferior vein draining directly from segment 6 into the vena cava, and this must also be divided.

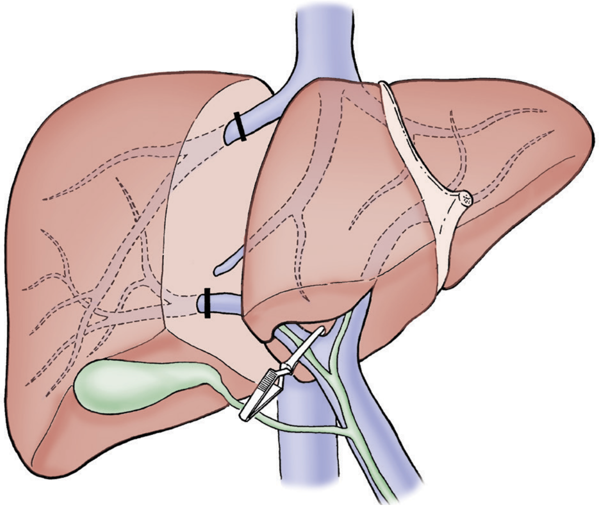

Figure 21.6 *A right hepatectomy. Temporary inflow occlusion to the right half of the liver has been secured with a clamp at the porta hepatis. Definitive ligation of the structures of the right portal triad can wait until they are encountered in the plane of the dissection.*

The right hepatic vein may be divided and sutured by an extrahepatic approach, after the right hepatic artery and portal vein have been secured. Alternatively, the right hepatic vein may be dealt with from within the liver during the later stages of parenchymal transection. The advent of newer vascular stapling devices for dividing and stapling the vein has made the extrahepatic approach a more favourable choice.

After division of the portal structures to the right hemiliver, together with all parenchyma between the two hemilivers, and division of all hepatic veins draining the right liver, the right hepatectomy has been completed. The cut surface must be checked for bile leaks from any unsecured biliary radicle. Typically, a white swab is used to identify any spot of green bile. Any leak thus identified is then sutured with fine Prolene® sutures. Finally, haemostasis must be ensured after removal of any occlusion clamp. Time should be taken to allow the anaesthetist to administer fluids to raise the arterial pressure and CVP to normal levels. Any bleeding site is sutured and the cut surfaces are covered with haemostatic aids; for example, fibrin glue reinforced with collagen sheets.

Left hepatectomy

This excision is along the anatomical plane between the two halves of the liver. Segments 1, 2, 3 and 4 are removed. Full mobilisation of the right lobe enables it to be rotated forwards with packs behind it, thereby making the transection plane between the two halves of the liver easier. However, the retrohepatic IVC does not need to be cleared on the right side. The left half of the lesser omentum is divided, and it is important to check within it for an accessory left hepatic artery arising from the left gastric artery. The gallbladder is removed if necessary. The principles of the portal dissection to ligate or control the structures in the left portal triad are similar to those required for the right portal triad in a right hepatectomy. As before, the left hepatic artery and the left portal vein are suture-ligated first, and the duct divided during transection. The dissection along the plane between the two halves of the liver is similar to that described for a right hepatectomy, but on this occasion the dissection, which is made 5 mm inside the ischaemic half, is to the left of the middle hepatic vein. The vein is preserved, but tributaries to it from the left half of the liver are ligated and divided. The left hepatic vein must be secured with a sutured or stapled closure. There are additional hepatic veins draining directly into the vena cava from the caudate lobe (segment 1) and these must be secured if the caudate lobe is to be removed. This is normally done at the outset by developing a plane between the left side of the IVC and the left caudate.

Segments 2/3/4 segmentectomy

Segments 2/3/4 segmentectomy is a modification of a left hepatectomy in which the caudate lobe (segment 1) is retained. This is a more common procedure, as most tumours do not encroach onto the caudate lobe. In the porta hepatis the left hepatic artery and portal vein are ligated, but preferably distal to the branches that run posteriorly into the caudate lobe. The anatomy of the caudate lobe is complicated.[9] However, this lobe receives arterial and portal inflow from both halves of the liver, and the biliary drainage is similarly split. The venous drainage is directly into the IVC. Part or all of the caudate lobe can therefore be retained in a left hepatectomy.

Left lobectomy (segments 2/3 segmentectomy)

This is the excision of the two segments lying to the left of the falciform ligament. The falciform ligament, the left triangular ligament and the left end of the lesser omentum are all divided to increase mobility, and the left liver is rotated forwards and packs placed behind it. The resection is immediately on the left side of the falciform ligament, and is a relatively easy plane to follow. CUSA dissection is ideal for the small bridge of liver parenchyma that crosses the fissure between the lobes. The umbilical ligament is first followed deep into the umbilical fissure. This brings the dissection directly onto the left portal triad and its main biliary and vascular branches to the segments of the left liver (Figure 21.7). The segmental branches to the segments to be excised are ligated and divided. The branches of the portal triad that turn back to segment 4 are preserved (see Figure 21.4). Superiorly, the left hepatic vein is in the plane of the dissection, lying near the upper end of the fissure between the lobes. It is more superficial than is sometimes anticipated, and care must be taken not to damage the vein before it can be safely isolated, ligated and divided.

Extended right hepatectomy

In this resection, segments 5, 6, 7 and 8 of the right liver are excised with the addition of segment 4 from the left liver. Segment 1 may be included in the resection if segments 2 and 3 are of a size to leave a physiologically competent remnant. The first step is to mobilise the whole liver and rotate it to the left to secure the small tributaries draining into the vena cava, as described for a right hepatectomy. The gallbladder is removed and the dissection in the porta hepatis isolates the right branches of the portal triad in a similar manner to the dissection for a right hepatectomy. They are then usually ligated and divided at this stage rather than merely controlled. The plane of dissection is on the *right* side of the falciform ligament. The vascular and biliary structures supplying or draining the segments to be retained should lie protected on the left of the falciform ligament during the initial dissection, but great care must still be exercised to avoid any damage. The branches turning back from the right portal triad to segment 4 are isolated. Once the segmental branches to segment 4 can be identified and ligated, a line of demarcation will aid further dissection.

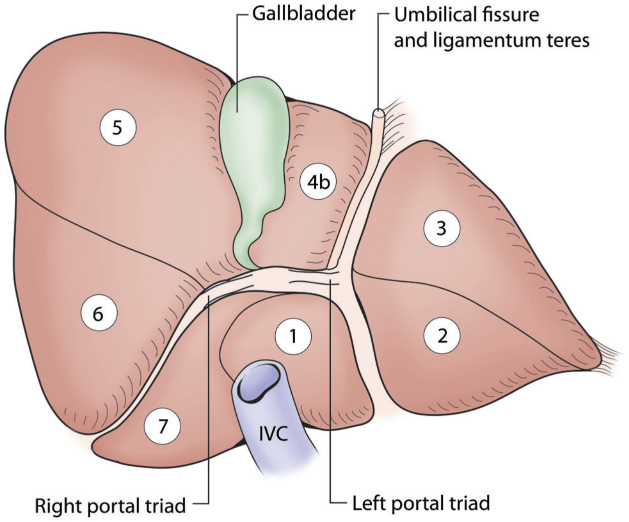

Figure 21.7 *The liver viewed from its inferior aspect. The ligamentum teres (umbilical ligament) can be followed to the left portal pedicle deep in the umbilical fissure. Gallbladder tumours can invade segments 4 and 5. Hilar cholangiocarcinoma can also invade segment 1, while adrenal tumours can invade the adjacent liver of segments 1 and 7.*

Extended left hepatectomy

This resection includes the removal of segments 5 and 8, in addition to the left hemiliver. However, segment 1 is often retained. The operation commences with a dissection in the hilum, as for a left hepatectomy. The position of the ligatures on the structures of the left portal triad will depend on whether segment 1 is to be excised or preserved; a ligature can be placed more distally to preserve a vessel or duct to this segment. The line of the parenchymal dissection is at the anterior border of segments 6 and 7. There are no reliable surface markings to identify this nearly horizontal plane between the anterior and posterior portions of the right liver. It is usually not possible to obtain early control of vascular inflow to create a line of demarcation. However, intraoperative ultrasound can show the position of the right hepatic vein, which drains from all four segments of the right liver and lies in the horizontal intersectional plane: segments 5 and 8 lie anteriorly and segments 6 and 7 posteriorly. In practice, packs are placed behind the right lobe of the liver to shift the liver as far forward as possible. As a consequence, the liver is also rotated and the anatomical plane between 5/8 to be excised and 6/7 to be retained moves from horizontal to near vertical, similar to the orientation shown in Figure 21.4. It must be remembered that the position of the right hepatic vein is also shifted forwards, putting it at risk during dissection. The vein is thus a useful landmark also for right-sided segmentectomies. When early inflow occlusion is not possible, a Pringle clamp is of particular value. An extended left hepatectomy is extremely challenging, and an accurate map of the right-sided portal structures is crucial.

Segments 6 and 7 segmentectomies

These segments may be excised together or one segment may be excised on its own. The planes between segments are difficult to identify by external landmarks, and the anatomy does not always lend itself to vascular control to show lines of demarcation before parenchymal dissection. Ultrasound identification of the right hepatic vein is often the only landmark. Alternatively, the intersectional plane (between segments 5 and 8 anteriorly and segments 6 and 7 posteriorly) runs in a horizontal plane, starting at the midpoint between the gallbladder and the right extreme edge of the liver.

Segments 1, 4, 5 and 8 resections

These resections may be performed in isolation as single segmentectomies or as part of a major resection of the central liver. Both the caudate and the quadrate lobes can be divided into segments, which can be preserved or removed independently. Segment 4a is superior or cranial and may be removed in isolation or in combination with a right hepatectomy. This preserves segment 4b as an extra 5–10 per cent of functioning liver. This usually entails excision of the middle hepatic vein, but great care must be taken to preserve the umbilical vein. Segment 4b is caudal and inferior. It may be removed in isolation, as for a small secondary colorectal deposit, or combined with the adjacent segment 5 if this is also involved in the pathology (see Figure 21.7). A radical resection for cancer of the gallbladder may necessitate either a segments 4b/5 segmentectomy or a 4b/5/6 segmentectomy. Resections in the central portion of the liver may be confounded by the proximity of the lesion to be excised to the structures of the porta hepatis and the IVC. An intact vascular inflow and outflow – as well as biliary drainage – to any remaining liver must be preserved, or reconstructed, and an understanding of the anatomy is essential both in the planning and the execution of these resections. Vascular anomalies can sometimes make a resection impossible, but on other occasions they may make a resection unexpectedly feasible. For example, a large posteroinferior accessory right hepatic vein draining directly into the IVC allows the sacrifice of both the middle hepatic and right hepatic veins if they are involved in a tumour.

The dissection for these central segmentectomies follows the planes already described but, as selective inflow occlusion to the individual segments before parenchymal division is not possible, there is no line of demarcation to follow. Portal control of vascular inflow with a Pringle clamp will be essential to reduce blood loss. Further details of these resections are beyond the scope of this book, but further reading on this subject is recommended.[10]

LIVER TRANSPLANTATION

This specialised subdivision of liver surgery must only be attempted within the discipline of a transplant unit. Many specialist liver surgeons will practise outside such a unit and will have no involvement in this field. However, an understanding of the issues involved is important for all surgeons specialising in the liver, as liver transplantation is sometimes one of the treatment options. In addition, if the possibility of a future transplant has not been considered, surgery that is undertaken in the interim may make a transplant more difficult.

The commonest indication for liver transplantation in the adult is deteriorating liver function from progressive chronic liver disease, including primary biliary cirrhosis and primary sclerosing cholangitis, in addition to cirrhosis secondary to viral infection or alcohol. In children, the commonest indication is biliary atresia and the progressive cirrhosis that ensues when a portoenterostomy performed for this condition fails to establish adequate biliary drainage (see Chapter 19). A transplant can sometimes make excision of an intrahepatic malignancy possible, and is also occasionally an option in fulminant liver failure as, for example, after a paracetamol overdose.

Surgical options

The standard cadaveric liver transplant includes the donor liver with the retrohepatic IVC. It also includes the donor common bile duct, portal vein and hepatic artery. The recipient liver is excised with the retrohepatic IVC. The recipient common bile duct, portal vein and hepatic artery are divided close to the porta hepatis. The anastomoses shown in Figure 21.8 are then performed. Alternatively, a piggy-back technique is used wherein the recipient IVC is retained, to which the donor supra-hepatic IVC is anastomosed end-to-side.

The need for paediatric donor livers always outstrips the availability, and a variety of techniques have been developed to implant a portion of an adult liver.[11,12] A left hemiliver or a segments 2/3 graft is suitable. From this developed the expertise to split a donor liver and use the larger part for an adult recipient and the smaller for a child (Figure 21.9). More recently, the practice of using live, related donors for children has become increasingly popular, although the not insignificant risk to the donor has deterred some surgeons from utilising this approach.

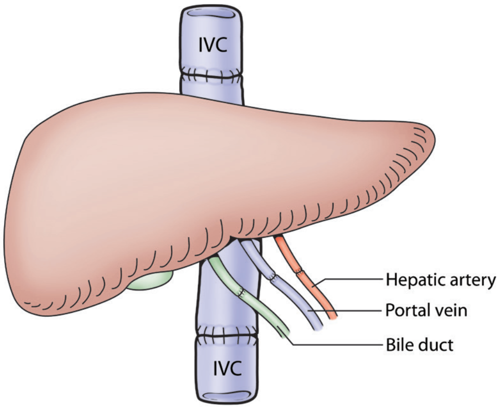

Figure 21.8 *A liver transplant. The donor inferior vena cava (IVC) is anastomosed end-to-end to the recipient IVC above and below the excised diseased liver. Anastomoses are constructed between donor and recipient hepatic artery, portal vein and bile duct.*

POSTOPERATIVE AND POST-TRAUMATIC COMPLICATIONS

Emergency surgery for liver trauma was discussed in Chapter 15. The emphasis of management has shifted in favour of a more conservative approach. Often, no action is required other than careful monitoring, with the infrequent addition of radiological endovascular intervention. Any surgery is usually restricted to packing of the liver to control bleeding, but the occasional patient requires either an emergency resection for uncontrollable haemorrhage or a later intervention for a post-traumatic complication. The range of complications following trauma is similar to those that may be encountered after liver surgery, and they will therefore be considered together. Postoperative haemorrhage, bile leaks and liver failure are now graded according to a new classification.[13,14,15]

Haemorrhage

Early post-traumatic and postoperative haemorrhage can often be managed expectantly with blood replacement.[13] However, a coagulopathy must first be excluded or corrected. If time allows and there is radiological expertise available, significant haemorrhage is best managed by angiography and embolisation of a bleeding artery. If the patient decompensates and interventional radiology is not available, then a laparotomy is mandatory. In the trauma situation, packing of the liver is advised (see Chapter 15). In contrast, in early haemorrhage after surgical resection, oversewing of bleeding points is necessary. Secondary postoperative or post-traumatic haemorrhage is often associated with infection. The tissues are extremely friable and the only surgical intervention possible is usually packing of the bleeding area. Angiography and embolisation of the bleeding vessel is a much better alternative if the radiological skills are available.

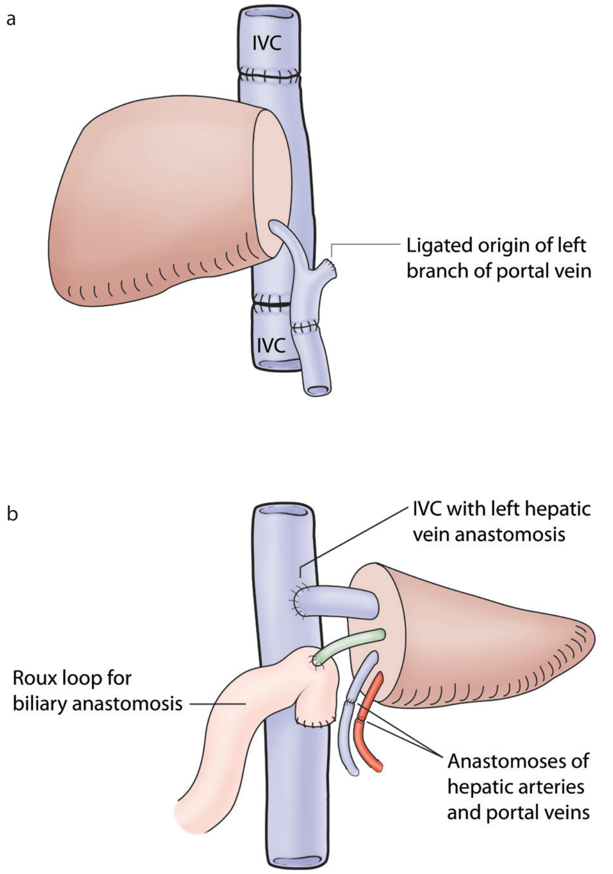
a
IVC
Ligated origin of left branch of portal vein
IVC
b
IVC with left hepatic vein anastomosis
Roux loop for biliary anastomosis
Anastomoses of hepatic arteries and portal veins

Figure 21.9 *Split liver transplant techniques enable an adult to receive the right liver and a child to receive segments 2/3. (a) The right liver is transplanted with the donor vena cava. The donor portal vein and hepatic artery, with the origins of their left branches ligated, are anastomosed to the recipient portal vein and hepatic artery. The donor common bile duct, with its left hepatic duct confluence ligated, is anastomosed to the recipient common bile duct. For clarity, only the portal vein reconstruction is shown and the donor and recipient hepatic arteries and bile ducts have been omitted from the drawing. (b) Segments 2/3 of the liver are harvested with the left hepatic vein, the left hepatic duct and artery and the left branches of the portal vein: ducts or vessels to segments 1 and 4 are ligated. The left hepatic vein is anastomosed end-to-side onto the recipient IVC, and the left hepatic artery and the left branch of the portal vein are anastomosed to the recipient hepatic artery and portal vein. The left hepatic duct is frequently anastomosed onto a Roux loop.*

Haemobilia

Haemobilia – haemorrhage into the biliary tree – may follow trauma or surgery and it can also be a complication of almost any hepatobiliary pathology. Haemobilia implies the existence of a fistula between a vessel and a bile duct. Subsequent bleeding is into the gastrointestinal tract through the duodenal ampulla. A bleed may be major, with haematemesis and melaena, or persistent and of low volume, resulting in anaemia. Diagnosis is initially one of exclusion of other sources of gastrointestinal blood loss. Haemobilia is sometimes confirmed if blood is seen at endoscopy to be coming from the duodenal ampulla. Angiography can be confirmatory in showing the anatomical site of the fistula. However, if there is no active bleeding at the time of the examination, the angiogram may be normal, although an area of abnormal vascular anatomy may still be demonstrated. Unless an underlying pathology that requires surgical intervention is identified as the cause of the haemobilia, the treatment is by embolisation at angiography.

Liver failure

Liver decompensation after a major resection requires expert supportive management until the liver can recover.[14] If anticipated at the time of surgery, the effects may be ameliorated by intravenous acetylcysteine (Parvolex®; as used for paracetamol overdosage). This may improve oxygen delivery to the hepatocytes. Liver function must be carefully monitored and any metabolic abnormalities or coagulopathy treated. The prothrombin time is the most sensitive measure of liver function during this period. A gradual rise in serum bilirubin of 20–40 μmol/l per day is usually indicative of liver failure as a consequence of a small liver remnant. When the bilirubin level reaches a plateau it indicates a favourable prognosis. During this period the initial rise in liver transaminase activity, seen as a consequence of the Pringle clamp injury, should fall if there is no concomitant injury to vascular structures. By 1 week after surgery the serum alkaline phosphatase level should start to rise, indicating liver hypertrophy that continues for 2 to 3 months. During this period, oral administration of the choleretic ursodeoxycholic acid (250 mg three times daily) may help.

An unexpected decompensation should alert the surgeon to the possibility of a surgical complication. An area of liver may be ischaemic or have necrosed. A portal vein thrombosis may have developed. If the liver remnant was not secured at the time of surgery, it may have rotated and kinked its vascular inflow or drainage. There may be a bile leak or an infection. These complications are best identified by ultrasound and CT examination. Any collection must be drained. Likewise, a bile duct obstruction that presents as a sudden rise in both serum bilirubin and alkaline phosphatase must be drained percutaneously.

Liver necrosis, cysts and abscesses

A small area of liver necrosis may absorb spontaneously, and progress can be monitored on serial imaging. If a cyst forms or if infection supervenes and a liver abscess develops, these are treated as outlined below. A large area of necrotic liver may be better excised early or better still identified and dealt with at the time of the original resection.

Bile leaks

Bile that is leaking from the biliary tree must be drained. In practice, the majority of leaks occur immediately after liver resection and are managed expectantly by leaving the drain placed at operation *in situ*.[15] Bile in the peritoneal cavity must be drained by percutaneous image-guided placement of a drain or, if this service is unavailable, by laparotomy. If bile is draining through a drain left at the time of surgery, it must be established by imaging that it is draining all the leaking bile and that there is no additional collection. Many bile leaks will seal spontaneously and a steady reduction in the volume that drains is reassuring while spontaneous closure is awaited. The management of larger-volume leaks that fail to close depend on the underlying problem. Biliary imaging is necessary to define the anatomy of the leak and exclude biliary obstruction distal to the leak that is preventing spontaneous closure. Surgery to repair a large duct or secure a small duct is seldom indicated in the acute situation. Persistent or high-volume leakage may imply injuries to larger ducts. This may require endoscopic retrograde cholangiopancreatographic (ERCP) stenting or a sphincterotomy to reduce biliary pressure. Biliary reconstruction at a later date may have to be considered. Peripheral leaks will usually eventually close, but a persistent biliary fistula should be re-explored. If the duct cannot be satisfactorily closed, a Roux loop can be brought up to the area to secure internal drainage of the fistula back into the gastrointestinal tract. The need for this rather major intervention is fortunately rare, as most bile leaks after trauma or resection settle by good conservative management.

SURGERY FOR LIVER INFECTIONS

Pyogenic liver abscesses

Pyogenic liver abscesses may develop as a result of bacteria in the systemic circulation, portal vein or within the bile ducts. A systemic bacteraemia can occur from a variety of underlying pathologies, including bacterial endocarditis and intravenous drug abuse. A portal pyaemia can occur with any infective pathology in the gastrointestinal tract, including appendicitis, and a liver abscess is occasionally the presenting feature of a colonic cancer or intestinal Crohn's disease. Ascending cholangitis may also be complicated by the formation of liver abscesses. The patient has symptoms and signs suggesting sepsis, but often none that localise the source of the sepsis to the liver. To make the diagnosis, a liver abscess must first be suspected and then excluded or confirmed.

Treatment is with image-guided drainage and antibiotics, adjusted by sensitivity testing of any bacteria grown from the pus drained. A drain should be secured into the abscess cavity and left on free drainage until all drainage has ceased and the cavity has been shown to have collapsed on repeat imaging. Occasionally, the drain becomes blocked and may require unblocking by saline injection under sterile conditions. The antibiotic regime should also be intensive and prolonged as otherwise recurrence of infection can occur. Initially, intravenous therapy is instituted to ensure high blood levels. Oral antibiotics should then be continued for up to 6 weeks; the choice of antibiotic regime will depend on culture of the pus drained.

The management of pyogenic liver abscesses is more difficult for surgeons who are practising in areas with no access to sophisticated imaging. The diagnosis is often delayed and, even with a high incidence of clinical suspicion, a liver abscess is still difficult to confirm. At laparotomy, pus can be confirmed and the abscess localised by needle aspiration. Open drainage of pus can then be instituted with the introduction of a soft drain into the abscess cavity. The drain is brought to the abdominal wall by the shortest intraperitoneal route and out to the skin through a separate stab wound. Thereafter, the management is similar. If more sophisticated modalities to check shrinkage of the cavity are unavailable, a slow removal or 'shortening' of the drain over a period of 1 week or more is recommended. A sinogram can also be of value.

Amoebic liver abscesses

Aspiration of a large amoebic liver abscess was once a common bedside procedure in endemic areas even after the introduction of metronidazole. Image guidance was seldom available and a point was simply chosen over the grossly enlarged liver where there was maximum tenderness, usually laterally just above or below the right costal margin. Local anaesthetic agent was infiltrated and, with full sterile precautions to avoid a superimposed iatrogenic pyogenic infection, a wide-bore needle, attached to a large syringe was advanced into the liver. A three-way tap was required as over 1 litre of 'pus', consisting of necrotic liver cells mixed with blood, was frequently obtained. Repeat aspirations, if necessary, were preferable to a drain left *in situ*. Metronidazole alone has now been shown to be effective even in large collections and aspiration is now seldom undertaken. A ruptured amoebic liver abscess presents with acute peritonitis. Ultrasound-guided peritoneal drainage and metrodidazole have proved preferable to operative management.[16]

Ascaris lumbricoides

If these intestinal worms enter the biliary tract through the duodenal ampulla, they cause intermittent partial obstruction, irritation and infection. The resultant combination of calculi and fibrous strictures may involve both the extrahepatic and the intrahepatic ducts. The management is discussed further in Chapter 19.

Hydatid disease

Hydatid disease is caused by *Echinococcus* spp., a parasite whose life cycle passes alternately through dogs and sheep. In sheep it is within visceral cysts, while in the dog it is a small intestinal worm. The human infection, in the form of a visceral cyst, is contracted from an infected dog. The incidence of the disease thus shows great occupational and geographical variation. *E. granulosus* and *E. multilocularis* are the two species commonly associated with human infection. The latter is more aggressive and requires a more active approach to management. One or more cysts containing viable parasites develop in the liver. They grow slowly and many are asymptomatic for years. Large cysts may cause pain or jaundice from pressure. Secondary infection and rupture also occur.

Small calcified asymptomatic cysts in the elderly may not require any intervention, but for most patients treatment is recommended. There has been a recent increase in interest in aspiration and scolicidal injection techniques (Percutaneous Aspiration, Injection and Re-aspiration – shortened to PAIR) in selected patients.[17] However, any communication with the biliary tree must be excluded or there is a risk of sclerosing cholangitis. It is also an unsuitable technique if there is secondary infection.

For most patients surgery should be recommended.[18] Many liver surgeons advocate a formal resection. The older technique of excising only the cyst may, however, be a safer option for a surgeon unable to transfer a patient to a specialist unit. It may also be a more suitable operation for very large cysts or those that abut major intrahepatic structures. With a Pringle clamp in place, an incision is made through the liver parenchyma until the ectocyst is exposed. This appears as a discrete capsule, but consists only of condensed normal liver tissue. The ectocyst is incised to expose the rubbery endocyst, which is only lightly adherent to the ectocyst, and is separated gently from it so that the endocyst with the parasites inside can be delivered intact. Initial aspiration of the cyst from within a controlling purse-string suture may make removal easier. It is very important not to rupture the endocyst with subsequent spillage of viable parasites. To reduce the consequences of such a mishap, the liver is surrounded by packs soaked in a scolicidal solution, such as hypertonic saline. The operation is also usually covered with a anthelmintic agent. Injection of scolicidal agents into the cyst is dangerous if there is a connection from the cyst into the biliary tree. This communication is also the cause of postoperative bile leaks. The inside of the residual ectocyst should be examined and if any bile leaks are found, they should be sutured. Omentum is frequently packed into the liver cavity, but alternatively the area can be left open to the peritoneal cavity.

SURGERY FOR NON-INFECTED LIVER CYSTS

Simple cysts

Single or multiple liver cysts are often visible or palpable at laparotomy or laparoscopy. There is sometimes initial diagnostic uncertainty and concern about malignancy. Liver cysts are also a common incidental finding on imaging. Small asymptomatic cysts require no treatment. The occasional cyst may grow to a large size, compress the surrounding liver and distort the vascular or biliary anatomy. Pain and, less commonly, jaundice precipitate intervention. Percutaneous aspiration should not be attempted as the cyst invariably re-accumulates and may bleed or become infected. Total excision is the treatment of choice, whether by dissection on the surface of the cyst or, more satisfactorily, by a formal liver resection. Conservative surgery, whether fenestration or marsupialisation, is often disappointing as recurrence is likely if a significant portion of the cyst wall is left *in situ*. However, as these cysts are large and have caused compression and distortion of the intrahepatic anatomy, a segmentectomy or hemihepatectomy required for their removal may be technically challenging. Cysts that hang off the inferior aspect of the liver may be managed by laparoscopic deroofing as long as the majority of the cyst wall can be easily removed. Occasionally, cysts are malignant. While imaging characteristics may highlight the possibility of malignancy, it can be extremely difficult to distinguish with certainty between a benign and a malignant cyst. It is therefore prudent to excise symptomatic cysts intact if at all possible.

Biliary cysts

Occasionally, a cyst in the liver is found on preoperative imaging to communicate with the biliary system. These rare cysts, which are most often a complication of biliary surgery or trauma, can be drained internally with a cystoenterostony onto a Roux loop.

SURGERY FOR LIVER TUMOURS

Haemangiomas and benign neoplasms

The advent of scanning the liver by ultrasound, CT and MRI has led to the coining of the term ‘incidentaloma’. In other words, innocent abnormalities are discovered as a by-product of scans performed for non-related symptoms or for the monitoring of unrelated pathologies. The culprits include haemangiomas, adenomas, focal nodular hyperplasia and cysts. Characterisation of these lesions may be straightforward, but they can be extremely difficult even for specialist hepatobiliary radiologists. If doubt remains, then a ‘trial of time’, with repeat scanning at 3–4 month intervals, will identify enlarging lesions that may be malignant. Surface bile duct adenomas, haemangiomas and cysts may also be encountered as incidental findings when the liver is inspected or palpated during laparotomy. Larger lesions may have a characteristic appearance enabling a reasonably confident diagnosis to be made, but small benign lesions can be difficult to differentiate from secondary deposits. A trial of time and repeat scans are again appropriate. As explained further below, the temptation to biopsy such a lesion for histology should be resisted.

Small capillary haemangiomas and bile duct adenomas can be safely left *in situ*. Larger cavernous haemangiomas may present with pain or obstructive jaundice and require excision by either segmentectomy or hemihepatectomy. Liver cell adenomas are associated with the contraceptive pill; they may grow to a large size and major haemorrhage, both into the tumour and into the peritoneal cavity, is sufficiently common that their removal is usually advised. They are excised as a hemihepatectomy or segmentectomy, depending on their location. A patient with a haemangioma or a liver cell adenoma may present as an emergency with a major intraperitoneal bleed. If at laparotomy a general surgeon encounters this situation, the treatment is packing to control haemorrhage, followed by transfer to a specialised hepatobiliary unit for a resection.

Very large cavernous haemangiomas in infancy can present with high-output cardiac failure. Spontaneous regression of an infantile haemangioma will often occur, and hepatic artery embolisation may be used to reduce the arteriovenous shunt and avoid the need for a resection. If this is unsuccessful and resection is not possible, a liver transplant is a further option.

Hepatocellular carcinoma

Hepatocellular carcinomas (HCCs) mostly arise within a liver that is already damaged by viral hepatitis or alcohol overuse. There is great geographical variation in incidence, and this tumour is much more common in Asia than in the West. This is partly related to the increased incidence of chronic viral hepatitis, but food carcinogens are a probable additional factor. Many patients are already under medical management for impaired liver function associated with cirrhosis, and the diagnosis is frequently made following investigations for a deterioration in liver function. Smaller, presymptomatic tumours detected on liver imaging are often initially difficult to differentiate from the regenerative nodules within a cirrhotic liver. Although there may be multifocal hepatic cell carcinomas at presentation, they often metastasise late and a potentially curative liver resection, which can offer around a 35 per cent 5-year survival, is the first option to be considered. Unfortunately, many of these lesions are irresectable at presentation, either because of their proximity to vital structures or, more frequently, because the physiological and regenerative reserve of the cirrhotic liver will not permit any major resection.

Liver transplantation has become an increasingly attractive option in the surgical management of small tumours in severely cirrhotic livers and should now be considered alongside resection as an alternative first-line treatment. The Milan criteria define patients with solitary tumours of less than 5 cm or with up to 3 tumours under 3 cm to be suitable for transplantation.

There are many methods of non-surgical tumour destruction. Percutaneous injection of alcohol into the tumour and tumour embolisation via the hepatic artery with lipiodol, either on its own or in combination with cytotoxic agents such as doxorubicin, can be very effective but, as these treatments cannot match the prognosis possible with resection, they should be reserved for situations where resection and transplantation are contraindicated. Radiofrequency-generated heat ablation or, more recently, microwave ablation has, however, proved so effective that it can be considered as an alternative first-line treatment for small tumours.[19]

HCC can present as an emergency with rupture and major intraperitoneal bleeding, and this complication is usually fatal. Liver packing to control haemorrhage, followed by transfer of the patient to a specialist liver unit for an emergency resection, may occasionally be successful.

Cholangiocarcinoma

Cholangiocarcinoma may arise from the extrahepatic ducts, from major intrahepatic ducts or from peripherally placed small bile ducts. Peripheral tumours, for reasons as yet unidentified, are increasingly common, and are resected as a hemihepatectomy or segmentectomy. The more centrally placed tumours within the liver may be amenable to resection by a central segmental approach. The surgery of hilar tumours was discussed in Chapter 19.

Secondary liver tumours

The pattern of metastatic spread of a malignancy can to a great extent be predicted by the origin of the primary tumour. For example, if a breast cancer spreads to the liver, it is commonly in the form of many hundreds of tiny deposits and it usually occurs at the same time as secondary deposits also develop in the lungs, the bony skeleton and the bone marrow. In contrast, a metastatic colorectal cancer may result in only one or two secondary deposits in the liver, with no metastases to other organs. While the deposits from the former tumour are obviously unsuitable for surgical excision, excellent results have been obtained from excision of the latter. Cures are undoubtedly achieved, and the 5-year survival figures after resection are of the order of 30 per cent. Most liver resections for secondary malignant deposits are for colorectal cancer, but other tumours, especially secondary sarcomas, should also be considered if complete tumour removal is possible. The benefit from palliative cytoreductive resections is limited almost exclusively to neuroendocrine tumours.

DETECTION

If a colorectal surgeon waits for a liver secondary to become palpable or symptomatic, it is usually too late to offer a resection. Therefore, it is now routine to screen the liver at the time of the initial bowel resection and to include regular liver imaging during follow-up. The frequency and modality of such imaging vary in different units, but a yearly ultrasound scan for 5 years is a reasonable compromise between what is desirable and what is affordable. The limitation of ultrasound has prompted increased use of annual CT scans if available and affordable. When an abnormality is detected, further more sophisticated imaging with MRI will usually clarify whether the abnormality represents a secondary deposit. In cases of doubt the situation is watched and scans repeated in 3–4 months time. There is, however, no justification for watching a solitary secondary growing over a number of years before considering surgery. A large solitary secondary, even when fully excised, carries a worse prognosis than an R0 resection of multiple smaller deposits.[20] This is because of metastases from the metastasis. Secondary deposits in the liver may invade intrahepatic veins with resultant tumour emboli and systemic spread. The invasion of portal vein branches results in metastases within the liver itself, both locally in the same segment and also in adjacent segments.

SELECTION

Most patients who were fit enough for the original bowel resection should be considered for surgery for resectable liver secondaries. Age in itself is not a contraindication. A liver resection in the presence of resectable extrahepatic metastases (e.g. lung deposits) is often still justified; these patients can be offered up to a 40 per cent 5-year survival with resection of both sites of disease. However, extensive pulmonary metastases are a contraindication to a liver resection and should be excluded by preoperative chest CT scanning. Para-aortic nodal disease, local pelvic recurrence or peritoneal seedlings are also contraindications to a liver resection. The two former metastatic situations can be diagnosed on preoperative abdominal and pelvic CT or MRI scans, but peritoneal seedlings are best excluded by a laparoscopy before an abdominal laparotomy incision is made. A laparoscopy is therefore recommended in patients whose primary tumours were originally unfavourable and also in patients who, because the primary tumour had perforated or had invaded through the peritoneum, have an increased risk of peritoneal metastases. The availability and cost of positron emission tomography (PET) scanning still limit its place in the detection of extrahepatic disease. False-positive and false-negative results are also still a problem, but PET scans have become an increasingly valuable investigation, especially in patients who had heavy nodal involvement at the time of the primary surgery and in those who are on the borderline of acceptance for liver resection.

Resection may be a curative option even when there are secondaries in both the right and left liver, provided that all the secondaries can be removed while preserving sufficient liver. Resections may take the form of hemihepatectomies, segmentectomies or localised excisions. Local excisions are most often used for an additional small secondary not included in the major resection. There is, however, seldom any place for a resection that does not remove all the intrahepatic disease. Imaging can be used to predict operability and to plan the surgery with accuracy. However, at the time of laparotomy, 5–15 per cent of patients may still be found to be inoperable.

It must be remembered that patients who have liver secondaries at the time of presentation of the primary tumour do not necessarily have incurable disease. The liver resection can be carried out at the same time as the bowel resection, except when both require a major procedure. For example, a right hemicolectomy can be combined with a right hepatectomy and an anterior resection with a segments 2/3 left lobectomy, but if a patient requires an anterior resection and a right hepatectomy, the liver resection should be deferred for a second operation. A temporary defunctioning stoma in the right hypochondrium, and the timing of its closure, can be an additional surgical challenge. There is also the question of the optimum timing of surgery and chemotherapy. Increasingly, chemotherapy is advised prior to liver resection. Advantages include earlier control of possible systemic micrometastases, down-staging of the liver secondaries and a prognostic indication: a tumour that progresses on chemotherapy has a poor prognosis even if still resectable. Disadvantages include the preoperative chemotherapy insult to the liver and lesions that become undetectable but are still viable. The psychological implications associated with the delays in definitive surgery to remove the cancer or to close a stoma should also not be forgotten.

Repeat resections when a patient develops further secondary deposits in the liver following a previous liver resection should be considered on the same criteria as those used for a first liver resection. The prognosis is at least as good as on first presentation with liver secondaries. A repeat resection is made more difficult by the distortion of anatomy following regeneration of the remnant, in addition to adhesions and fibrosis.

Surgery is not the only effective treatment for liver secondaries. The lesions can be reduced in size, or even occasionally obliterated, by chemotherapy. There is also a large variety of techniques available for thermal or chemical ablation. However, for metastases that can be completely removed by surgical excision, no other modality can offer as good a prognosis as a liver resection.

EXTENDING THE POSSIBILITIES

The percentage of patients with colorectal liver metastases who are considered suitable for a liver resection is steadily rising. At the end of the 20th century, 10–20 per cent of patients with colorectal liver metastases were thought to be resectable. Ten years later this figure had increased to 30–40 per cent. Some patients who are initially unsuitable may still have a potentially curative resection by using some of the following strategies:

- *Preoperative chemotherapy*, especially with oxaliplatin and irinotecan, can shrink the periphery of a tumour away from vital intrahepatic structures, which must be preserved, and thus make a resection feasible. The liver is more difficult to handle at operation after chemotherapy, and it must be remembered that a liver after chemotherapy will have its functional and regenerative capacity at least temporarily impaired. These patients are also more vulnerable to postoperative septic complications if the preoperative course of chemotherapy is prolonged.
- *Staged resection* can be useful when there are metastases in both halves of the liver. For example, an initial right hepatectomy can be followed by a delay while the left liver hypertrophies to allow one or more segmentectomies to be undertaken on the left hemiliver, without embarrassing liver function. The accelerated growth of the remaining deposits in the regenerating liver during this delay must be taken into account.
- *Portal vein embolisation* will induce a 40–60 per cent increase in the size of that part of the liver that has not been embolised. This is an image-guided procedure carried out by an interventional radiologist and may be of value when, for example, an extended right hepatectomy is planned but the remnant to the left of the falciform ligament is small. A disadvantage is that the portion to be removed has only hepatic artery inflow, which will favour metastases that may grow preferentially during the delay before surgery.

Combined stratagies are increasingly popular. For example, the initial clearance of the left liver with wedge excisions is combined with ligation of the right portal vein (or subsequent embolisation), followed by a right hepatectomy 4–6 weeks later.

Extrahepatic malignancies invading the liver

An extrahepatic malignancy may invade the liver by direct extension. When this occurs in a renal, gastric, oesophageal or colonic cancer it almost always represents an irresectable situation. However, occasionally, including when an adrenal, gallbladder or hilar cholangiocarcinoma is invading the liver, a resection is still sometimes appropriate, including resection of the affected segment of liver.

CYSTIC DILATATION OF THE INTRAHEPATIC BILE DUCTS

There is a wide range of aetiologies, including Caroli's disease, which probably represents an intrahepatic variant of choledochal cyst (see Chapter 19, p. 337). In addition, any condition that causes fibrous strictures can be associated with proximal dilatation. Presentation is with obstructive jaundice and recurrent biliary sepsis. There are often intrahepatic calculi. Drainage can sometimes be secured onto grossly dilated sections of the intrahepatic biliary system, but when the pathology affects only a localised area of liver, a resection is the treatment of choice. More often, the liver is more extensively involved. Repeated radiological or endoscopic access to the intrahepatic biliary tree will often be necessary. Therefore, consideration should be given to the provision of an access loop, as described in Chapter 19 (see Figure 19.13, 335). In some patients the only effective solution is liver transplantation.

PORTAL HYPERTENSION

Surgical management of portal hypertension is now mainly historical. Portal hypertension is caused by obstruction to venous drainage. This may be post-hepatic from hepatic venous thrombosis in the Budd–Chiari syndrome, intrahepatic from cirrhosis or prehepatic from obstruction of the portal vein. Whatever the aetiology, the pressure within the portal venous system rises and collateral channels open up between the portal and systemic venous beds. Many of these channels, such as those in the retroperitoneum, are harmless, but those at the gastric cardia produce oesophageal varices, which can present with torrential intraluminal haemorrhage. Historically, the surgery of portal hypertension was focused either on interrupting the portosystemic venous anastomosis at the cardia and direct ligation of the varices in an emergency, or on the reduction of portal pressure as an elective procedure.

Interruption of the portosystemic anastomosis at the cardia and direct ligation of the varices from within the opened oesophagus was a formidable undertaking in an emergency. Even before the oesophagus has been isolated there is often major bleeding from the upper abdominal wound secondary to anastomotic venous channels around the attachment of the falciform ligament, and the surface of the stomach has dilated subserosal veins coursing up towards the oesophagus. If a laparotomy has to be performed nowadays for uncontrolled variceal bleeding, the alternative transection and re-anastomosis of the distal oesophagus with a circular stapling device introduced through a separate gastrotomy (as illustrated in Figure 14.16, p. 239), is an easier solution. However, for surgeons still forced to tackle this emergency because of a lack of facilities for endoscopic sclerotherapy, a circular stapling device may not be an available option either.

The creation of a shunt between the portal and systemic veins reduces portal venous pressure and is effective in reducing the incidence of variceal bleeding. However, any shunt that reduces portal pressure also reduces portal venous perfusion of the liver, and this proves critical in some patients with significant hepatic impairment from cirrhosis. In an attempt to reduce the proportion of blood that was shunted, there was a move away from the original end-to-side portocaval shunt to a variety of other shunts (Figure 21.10). These included a splenectomy followed by the formation of an end-to-side anastomosis of the splenic vein onto the left renal vein (a proximal lienorenal shunt), the fashioning of a side-to-side shunt between the superior mesenteric vein and the

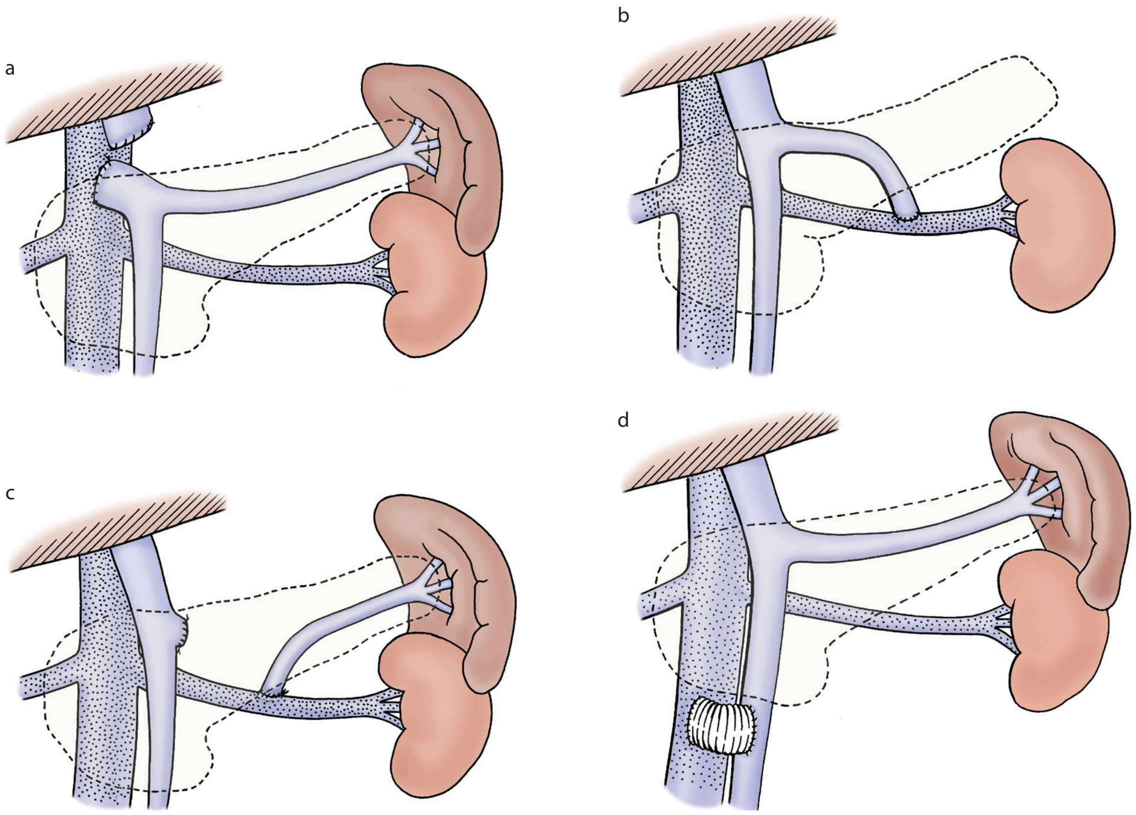

Figure 21.10 *Portacaval shunts. (a) An end-to-side portocaval anastomosis. (b) A proximal lienorenal shunt with splenectomy. (c) A Warren distal lienorenal shunt in which only the splenic component of the portal venous blood is diverted from the liver. (d) A mesocaval shunt with a Dacron 'H' graft. The diameter of the graft can be selected so that there is only partial portal-systemic diversion.*

IVC with a prosthetic graft (a mesocaval **H**-graft shunt) or the formation of an end-to-side anastomosis of the distal splenic vein onto the renal vein (distal lienorenal shunt), as popularised by Warren. These more limited shunts were less effective in the prevention of variceal bleeding, but were associated with a lower incidence of liver failure precipitated by the surgery.

In recent years the focus of management has returned to that of the varices themselves. They can be effectively sclerosed by endoscopic injection, both as an emergency measure to arrest haemorrhage and as an interval procedure to obliterate the varices and prevent a subsequent bleed. Very occasionally, a portosystemic shunt is still indicated, most commonly in patients with normal liver function and severe post-hepatic venous obstruction. A transjugular intrahepatic portosystemic shunt (TIPSS) is performed as an interventional radiological procedure and is created within the liver substance. This has the additional advantage that there is no distortion of the extrahepatic vascular anatomy, which is an important consideration if a liver transplant might be an option at a later stage. The place for an open surgical shunt is limited to situations where the facilities or skills to undertake a TIPSS are unavailable.

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22

CLASSIC OPERATIONS ON THE SMALL AND LARGE BOWEL

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ANATOMY

The small intestine

The *jejunum* begins as a direct continuation of the predominantly retroperitoneal duodenum at the duodenojejunal flexure. Distally, it is continuous with the *ileum*, with no line of demarcation. The ileum joins the medial wall of the caecum at the ileocaecal valve. The jejunum and ileum have a complete peritoneal covering and lie as free loops in the peritoneal cavity suspended on their mesentery. The *mesentery* contains, between its two layers, the arteries, veins, lymphatics and nerves of the small intestine. Its root, or line of attachment to the posterior wall, extends obliquely from the duodenojejunal flexure to the caecum.

The large intestine

An understanding of the surgical anatomy of the colon is dependent on an appreciation of intrauterine folding and rotation of the gastrointestinal tract, which is outlined in the embryology section in Chapter 14 (p. 228).

The *caecum* normally occupies the right iliac fossa; it is completely enveloped in peritoneum but has no mesentery, so it is relatively fixed in position. The *appendix* is attached to the posteromedial aspect of the caecum just below the ileocaecal junction, and the three taeniae coli of the caecum converge to end at the base of the appendix. The appendix is variable in position, but most commonly lies retrocaecally or, less frequently, lies with the tip free in the pelvis. A retrocaecal appendix may lie retroperitoneally, but in most cases the appendix has a complete peritoneal covering and its own mesentery in which runs the appendicular artery (Figure 22.1). An additional avascular fold of peritoneum extending from the front of the terminal ileum to the proximal appendix may be present.

The *ascending colon* is bound down to the posterior abdominal wall and is covered with peritoneum only on its anterior surface and sides. The *hepatic flexure* lies on the right kidney and the second part of the duodenum. The *transverse colon* is again freely mobile, since it has a complete peritoneal investment and a mesentery. A long transverse colon may hang down into the pelvis, but is easily distinguishable from the sigmoid colon by the attachment of the greater omentum to its lower border. The complex peritoneal folds around the transverse colon are easier to understand from an embryological viewpoint. At the *splenic flexure* the colon is again bound to the posterior wall and overlies the left kidney and is

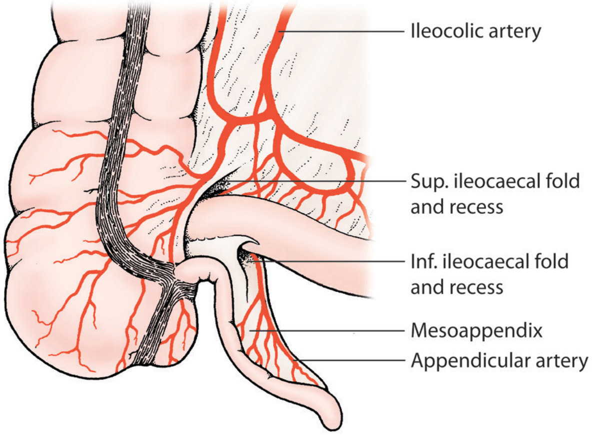
Ileocolic artery
Sup. ileocaecal fold and recess
Inf. ileocaecal fold and recess
Mesoappendix
Appendicular artery

Figure 22.1 *Anatomy of the appendix and ileocaecal region.*

closely related to the spleen, which lies superolateral to it. The *descending colon* is related to the posterior abdominal wall in a similar fashion to the ascending colon. The colon again becomes mobile on a mesentery as the *sigmoid* (or *pelvic*) *colon*. The sigmoid colon is of variable length and mobility and, as its extremities lie fairly close together, it is liable to volvulus. The large intestine again becomes fixed and finally totally retroperitoneal as the rectum.

The *rectosigmoid junction* has been defined as opposite the third segment of the sacrum, as the point where the taeniae spread out to form a continuous longitudinal muscle layer and as a measured distance from the anal verge. The distance used for the definition of this rather artificial junction, and hence the length of the rectum, has varied from between 12 and 15 cm from the anal verge. Standardisation is important for communication between surgeons with regard to the treatment of rectal and sigmoid cancer, and the junction between sigmoid colon and rectum has now been accepted as 15 cm from the anal verge when measured with a rigid sigmoidoscope.

The *rectum* lies in the concavity of the sacrum and ends by making an acute posterior angulation to become the anal canal. The upper third of the rectum is covered with peritoneum anteriorly and on each side; the middle third is covered only in front, while the lower third is entirely devoid of peritoneum because it lies below the pelvic peritoneum. Below the peritoneal reflection, the rectum is related anteriorly in the male to the base of the bladder, the seminal vesicles and the prostate, and is separated from them by Denonvillier's fascia. This fascial layer may represent the fused anterior and posterior peritoneum of the deeper rectovesical pouch, which was present during embryological development. In the female, the rectum is related anteriorly to the posterior vaginal wall, with a thin rectovaginal septum between rectum and vagina. The rectum has its own discrete 'mesentery' or *mesorectum*, which encircles the rectum, but the bulk of the mesorectum lies posteriorly in the concavity of the pelvis. There is an areolar plane between the mesorectum and the structures of the pelvic sidewall. This was not initially appreciated, but is of great importance in the surgery of rectal cancer.

BLOOD SUPPLY

The small and large bowels are supplied almost exclusively from branches of the *superior* and *inferior mesenteric arteries.* The jejunal and ileal branches of the superior mesenteric artery run in the small bowel mesentery. Three main branches from the superior mesenteric artery supply the large bowel proximal to the splenic flexure. The middle colic artery runs in the transverse mesocolon and the right colic and ileocolic arteries are retroperitoneal as they run towards the ascending colon and caecum (Figure 22.2). The inferior mesenteric artery runs a retroperitoneal course but, after full mobilisation of the sigmoid colon, it can be appreciated that in reality it is lying posteriorly within the pelvic mesocolon. It supplies the large bowel distal to the splenic flexure via the ascending left colic artery, the sigmoid arteries and its own continuation as the superior rectal artery into the mesorectum. The rectum also has a blood supply from the inferior rectal (haemorrhoidal) arteries, but the middle rectal arteries, which are described in older anatomy texts, are small and often absent. The arterial vasculature within the large bowel mesentery is arranged in a series of loops with interconnecting anastomoses. The large anastomotic channel close to the bowel is the *marginal artery.* It is this arterial anatomy that makes many large bowel resections possible and enables the surgeon to sacrifice the inferior mesenteric artery in infrarenal aortic prosthetic replacement surgery with only infrequent compromise to left colonic perfusion.

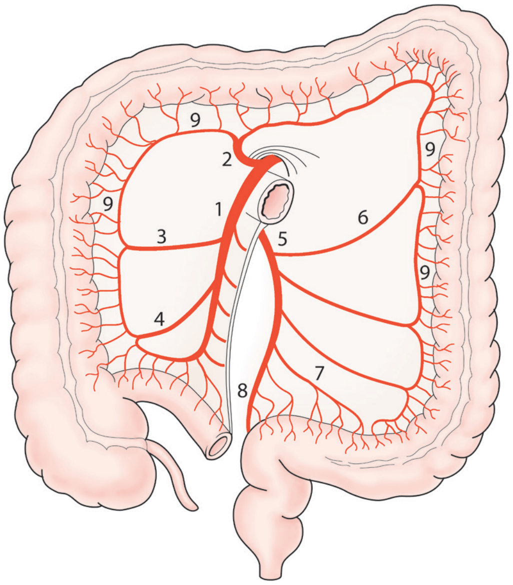

Figure 22.2 *The arterial supply of the large bowel. 1 = superior mesenteric; 2 = middle colic; 3 = right colic; 4 = ileocolic; 5 = inferior mesenteric; 6 = ascending left colic; 7 = sigmoid arteries; 8 = superior rectal; 9 = the 'marginal' artery, which consists of anastomotic arterial loops between individual arteries. The marginal artery may form an inadequate anastomotic channel at the watershed between the supply from the superior and inferior mesenteric arteries around the splenic flexure.*

The venous drainage of the intestines initially follows the arteries. The *superior mesenteric vein* lies on the right side of the superior mesenteric artery until it unites with the splenic vein to form the portal vein behind the neck of the pancreas. The *inferior mesenteric vein* lies lateral to the inferior mesenteric artery, and as it ascends above the level of origin of the artery it lies progressively more lateral. It disappears behind the pancreas in the vicinity of the duodenojejunal flexure to join the splenic vein (Figure 22.3).

LYMPHATIC DRAINAGE

The lymphatic drainage of the intestines follows the arterial supply. The only exception is the rectum. Although the rectum has an arterial contribution from the inferior rectal arteries, its lymphatic drainage is almost exclusively upwards

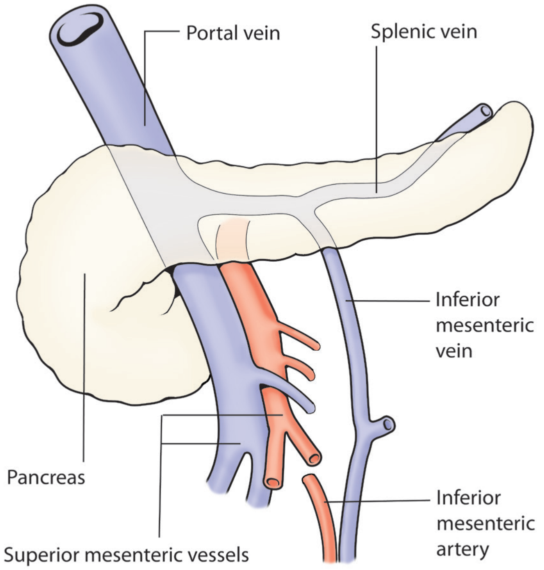

Figure 22.3 *Venous drainage of the bowel. The veins are lateral to the arteries.*

alongside the superior rectal artery and finally into the preaortic lymph nodes. However, some patients have lymphatic drainage to the lateral pelvic sidewall and this may account for pelvic sidewall nodal spread in some patients, particularly those with low rectal cancers.[1]

PELVIC AUTONOMIC NERVES

The multiple sympathetic fibres of the *superior hypogastric plexus* lie over the anterior surface of the aortic bifurcation and the left common iliac vein. They condense to form the two hypogastric nerves, which diverge as they cross the brim of the pelvis to the pelvic sidewall where each merges with the parasympathetic outflow from S2, 3 and 4 to form the *inferior hypogastric plexus* (Figure 22.4). This combined autonomic plexus lies as a fenestrated plaque on the pelvic sidewall. The largest parasympathetic contribution to the inferior hypogastric plexus is from S3, and this erigent nerve can be demonstrated during pelvic surgery as a sidewall pillar running up to the plexus. Anteriorly, the inferior hypogastric plexi turn medially and finally coalesce anteromedially on the anterior surface of Denonvillier's fascia as the *prostatic plexus* in the male.

The parasympathetic and sympathetic innervation of the pelvic organs is from small nerves from these pelvic autonomic plexi. Autonomic innervation of the bladder and sexual organs is from the prostatic plexus anterior to the rectum. Sympathetic innervation is essential for ejaculation and parasympathetic innervation for erection. Rectal autonomic innervation is from both inferior hypogastric plexi. The small rectal branches cross the areolar plane, between the parietal structures in the pelvis and the visceral contents, to enter the mesorectum. These nerves are the only autonomic nerve fibres that are intentionally sacrificed when the rectum is mobilised by dissection on the surface of the mesorectum.

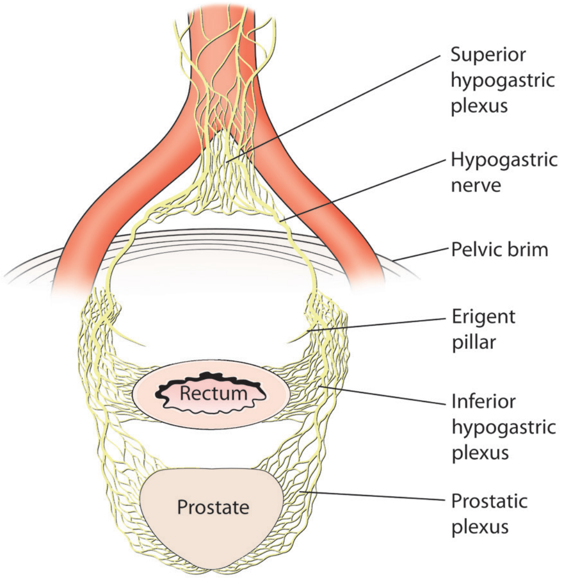

Figure 22.4 *The superior hypogastric plexus on the front of the aorta and the common iliac vein, the two hypogastric nerves at the pelvic brim, the inferior hypogastric plexus on the pelvic sidewalls and the prostatic plexus lying on the anterior surface of Denonvillier's fascia are all at risk in rectal surgery.*

All other autonomic nerves, although vulnerable to injury, are just outside this anatomical plane.[2]

APPENDICECTOMY

An appendicectomy is most commonly performed for acute appendicitis and can be performed by an open or a laparoscopic approach. Despite early scepticism, several studies have shown a faster postoperative recovery after a laparoscopic appendicectomy, which has now become the preferred option.[3] Patients also welcome the cosmetic result of the smaller laparoscopic scars and this is a more important consideration in an obese patient who would otherwise require a substantial incision for adequate access. Laparoscopy also has the advantage of allowing better inspection of the abdominal cavity and pelvic organs for other pathology.

The disadvantages of a laparoscopic appendicectomy are mainly those of cost. It is also possible that in the long term the incidence of umbilical port site herniae could compare unfavourably with the low incidence of incisional herniae from Lanz incisions.

Laparoscopic appendicectomy

A three-port technique is normally used. The first port is a 10-mm port for the camera and is established at the umbilicus. Additional ports are positioned to give access to the right iliac fossa for dissection. A suprapubic port and a port close to the left anterior superior iliac spine will achieve this. While 5-mm ports here are adequate for the dissection, the specimen will need to be delivered via a 10-mm port.

Unless a 5-mm camera is available to free up the umbilical port for specimen retrieval, one of these ports will need to be a 10-mm port. There is a risk of bladder injury with the suprapubic port and some surgeons advise routine temporary catheterisation to avoid the necessity of catheterising during the procedure if the bladder is found to be distended. The patient is placed in a Trendelenberg position so that the small bowel moves into the upper abdomen. If a normal appendix is seen, other pathology should be sought. If a clear cause for the patient's symptoms is found elsewhere in the abdomen, then it is reasonable to leave the appendix *in situ*, but otherwise an appendicectomy should be carried out, as appendicitis begins as a mucosal inflammation and in early disease the serosal surface may still appear normal.

Dissection may be required to bring the appendix into view. Adherent loops of omentum and small bowel can often be gently peeled away using blunt dissection with closed forceps. Picking up bowel directly with laparoscopic graspers should be avoided because of the risk of injury. Adhesions from the appendix to the abdominal sidewall may be divided with diathermy. When the appendix is lying retrocaecally, the first step in the dissection is release of the peritoneum lateral to the caecum so that the appendix can be delivered. The caecum is then retracted upwards to expose the base of the appendix, which can then be picked up. If there is difficulty mobilising the appendix laparoscopically, an early decision to convert to an open operation is prudent.

A window is then developed through the appendix mesentery, close to the base of the appendix. The appendix and mesentery are secured separately. The appendix mesentery can be divided with diathermy. While this is usually sufficient to control the small vessels within the mesentery, bleeding can occur. This bleeding can be controlled either with a clip or by grasping the bleeding vessel with a laparoscopic grasper and applying diathermy. Whichever strategy is planned, it is useful to ensure that the instrument required is readily available before starting to divide the mesentery. A tissue grasper is then passed through the noose of a pre-tied suture to hold the appendix. The appendix is delivered through the noose, which is then guided down to the base of the appendix and tightened. This manoeuvre is repeated and the appendix cut between the ligatures.

Port site contamination as the inflamed appendix is withdrawn should be minimised and a specimen bag should be employed. This is particularly important when there is a distended, severely inflamed or gangrenous specimen. The bag should be introduced and retrieved through one of the 10-mm ports. It is strongly recommended to close all 10-mm ports with secure closure of the fascia to prevent port site herniae.

Open appendicectomy

If the preoperative diagnosis is fairly certain, the surgeon will probably choose a small right iliac fossa incision (see Chapter 13). Pus may be encountered on opening the peritoneum, and is removed by suction. The first step is to deliver the caecum into the wound, and this can be difficult through the small incision. Small bowel loops lying anterior to the caecum are often repeatedly delivered to the surface. They can be differentiated from the caecum by their absence of taeniae. Occasionally, a long transverse colon is delivered in error, but it can be recognised by the attached greater omentum. The simplest method of isolating the caecum is to introduce an index finger lateral to all bowel loops and down into the paracolic gutter lateral to the caecum. It is then usually possible to hook the finger under a caecal taenia and to draw a portion of the caecum gently out of the wound. The taenia is then followed to its termination and the appendix delivered. If the appendix does not immediately deliver into the wound at this stage, a finger is reinserted into the wound along the taenia towards the caecal pole, where it is usually possible to feel the appendix as a tense cord, hook the finger around it and gently deliver it. If there is still difficulty, the wound must be enlarged for adequate access. The appendix may be wrapped in omentum, which can either be gently freed or a portion of adherent omentum excised with the appendix. The appendix may be lying retroperitoneally in a retrocaecal position and can be delivered only after lateral caecal mobilisation has allowed the caecum to be rotated medially and the appendix dissected out under direct vision. A superolateral muscle-cutting wound extension will usually be required to give sufficient access for this manoeuvre.

Once safely delivered, the appendix is held in a Babcock's forceps while the mesentery is viewed against the light to identify the anatomy of the appendicular vessels. A window in the mesentery near the base of the appendix allows application of an artery forceps and division of the mesentery (Figure 22.5a). It is often advisable to divide the mesentery in separate bites if the artery has divided early into individual branches, and this may also be safer in a fat-laden or oedematous mesentery. The arteries held in the artery forceps are then ligated. It is important that these forceps do not slip during ligation or the mesentery with the unsecured vessels may retract inside the abdomen and be difficult to re-secure. Back-bleeding from the cut distal end is usually minimal but, if troublesome, can be controlled temporarily with artery forceps. Care must be taken not to injure the terminal ileum or its mesentery during dissection of inflamed tissue. It is also important to remove the *whole* of the appendix. If an overgenerous appendix stump is left *in situ*, a further attack of appendicitis, with a dangerous delay in diagnosis, is possible.

The appendix is now attached only by its base. This is ligated with an absorbable suture (Figure 22.5b). Traditionally, the appendix base was crushed with an artery forceps prior to ligation. This was to reduce the swelling in the tissue to be ligated over a wider area than that compressed by the subsequent ligature, and thus reduce the likelihood of the ligature cutting through the oedematous tissue. Many surgeons no longer recommend this preliminary crushing manoeuvre. An artery forceps is placed 5 mm distal to the ligature. The appendix is then divided with a scalpel, cutting flush with the artery forceps (Figure 22.5c). The traditional purse-string

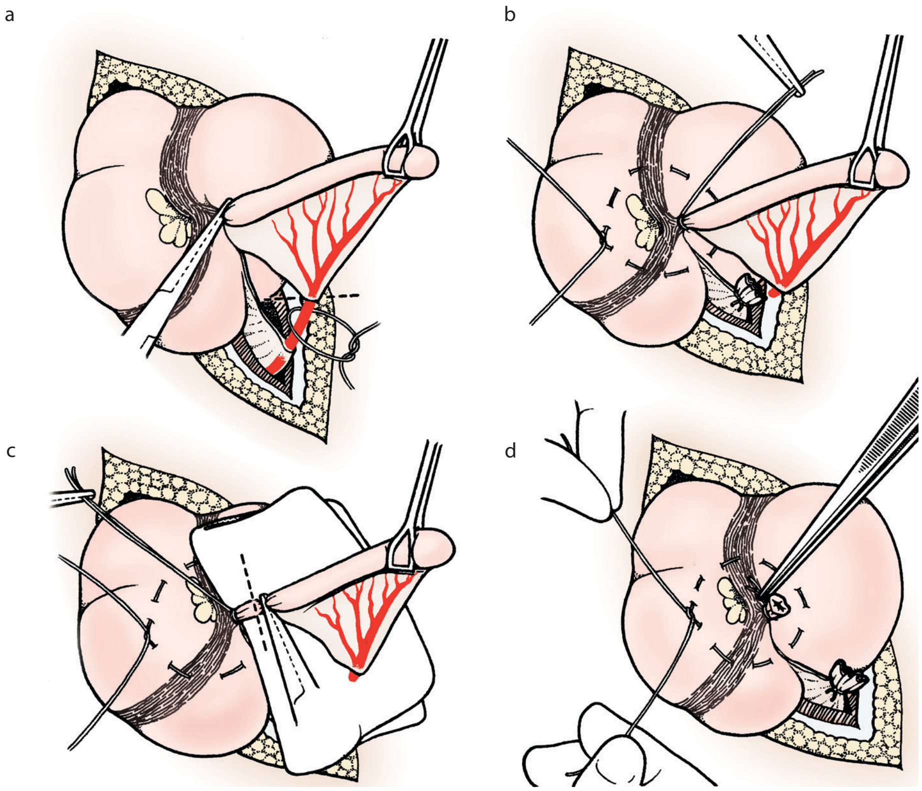

Figure 22.5 *Appendicectomy. (a) The appendicular vessels are ligated and the mesoappendix divided (the artery forceps on the appendicular vessels have been omitted for clarity). (b) The base of the appendix is ligated. If a seromuscular purse-string suture is used, it must be placed so that injury to vessels in the transected mesoappendix is avoided. (c) An artery forceps has been applied to the appendix distal to the basal ligature and the appendix is divided. Any spillage will be onto the underlying swab. (d) Pressure with the artery forceps invaginates the appendix stump as the purse-string suture is tightened.*

suture has also lost popularity. It is a seromuscular suture encircling the appendix stump. It can be inserted after ligation of the mesoappendix and either before or after the appendix is removed. Care must be taken when inserting a purse-string suture not to catch the vessels in the base of the divided mesoappendix. As the purse-string suture is tightened and ligated, the stump is inverted by pressure with artery forceps (Figure 22.5d). The argument for an invaginating purse-string suture is the possible deleterious effect of infected stump mucosa left exposed to the peritoneal cavity. It is also an extra closure should the ligature on the base of the appendix fail. Those who do not favour a purse-string suture argue that there is no evidence that the infected mucosa is harmful if left exposed, and that a purse-string suture merely traps any infection to form an intramural caecal abscess. All, however, agree that any attempt to place a purse-string suture in thickened oedematous tissue is contraindicated, as it will fail to invert the stump and will only cause damage to the friable caecal wall.

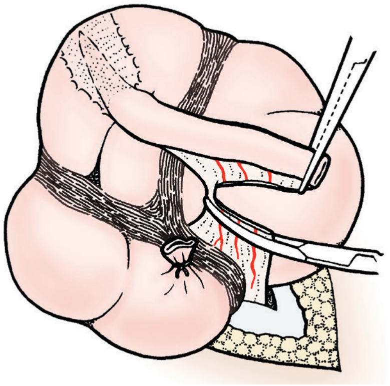

Figure 22.6 *A retrograde appendicectomy is a useful technique when the base of the appendix can be drawn into the wound, but the inflamed tip is difficult to deliver.*

Frequently, the base of the appendix is more accessible than the tip. If an inflamed retroperitoneal tip cannot be delivered into the wound, a retrograde appendicectomy – as described in the laparoscopic method – is a useful manoeuvre (Figure 22.6). Two pairs of artery forceps are insinuated through the mesoappendix and applied to the base of the appendix, 5–6 mm apart. The proximal forceps is then removed and the appendix ligated in the groove that has been crushed. The appendix is then divided close to the distal forceps, which is left on for retraction as the appendix is freed by dissection, and by successive clamping and cutting of its mesentery.

Special considerations in appendicectomy

GENERALISED PERITONITIS

An acutely inflamed appendix that has ruptured freely into the peritoneal cavity causes a generalised peritonitis. This is common in children, as the ability to localise and wall off an intra-abdominal infection is less well-developed, at least in part explained by the shorter omentum. In addition, in the pre-school child, presentation of appendicitis is often atypical and the diagnosis delayed. Surgery is urgent but relevant preoperative resuscitation should not be overlooked. The appendix is commonly easily accessible and is removed in the standard manner. All pus should be sucked from the peritoneal cavity, which is then further irrigated with saline or a bactericidal solution. A general peritoneal drain is of little value, but a wound drain should be considered in an open operation. A full therapeutic course of broad-spectrum antibiotics greatly reduces postoperative septic complications (see Appendices II and III).

LOCALISED APPENDIX MASS OR ABSCESS ENCOUNTERED AT APPENDICECTOMY

An acute appendicitis may be walled off from the general peritoneal cavity by adherent omentum or small bowel. Alternatively, if the appendix is lying retrocaecally, the inflammation is localised by the overlying caecum. Pus may form within the mass and the resultant appendix abscess may thus be either intraperitoneal or retrocaecal and mainly retroperitoneal, dependent on the position of the appendix. An inflammatory appendix mass is frequently palpable in the right iliac fossa preoperatively, but often only after the patient is anaesthetised and the abdominal wall relaxed. The presence of a mass is an indication that the operation may be more difficult and that more extensive access than usual may be necessary. Loops of small bowel involved in an appendicular inflammatory mass must be freed very gently, as the bowel will be friable. Omentum can be either separated from, or excised with, the appendix. When localised pus is encountered within the inflammatory mass and a drain has been placed into the depths of the abscess cavity after the appendix has been removed, this drain should be brought out through a separate incision.

DELAYED PRESENTATION

If a patient presents with a history of several days' duration and a large appendix mass without any signs of generalised peritonitis, conservative management with antibiotic therapy is often safer. Because of the perceived risk of a future attack, traditionally elective appendicectomy at 3 to 6 months has been recommended, although many now consider that removal is unnecessary.[4] In an older patient it is advisable to exclude an inflammatory episode associated with a caecal or colonic carcinoma by colonoscopy after the acute inflammation has settled.

If a patient with a delayed presentation and an appendix mass fails to improve on antibiotics, a significant collection of pus within the inflammatory mass should be suspected. This pus requires drainage. Where the equipment and skills are available, ultrasound or CT imaging can confirm a collection and, if confirmed, radiological image-controlled drainage is now an alternative for many surgeons. After drainage, the acute episode should resolve on conservative management and an interval appendicectomy can be planned if considered appropriate. When this radiological service is not available, the diagnosis must be made on clinical criteria and open operative drainage becomes indicated. This may be safely combined with an appendicectomy in most situations. However, the surgeon may encounter an inflamed appendix densely adherent to loops of friable small bowel, which are also forming the wall of the abscess. Simple drainage of the localised abscess and antibiotic therapy are safer than attempting an appendicectomy in these circumstances. Injudicious attempts to mobilise the appendix at the initial operation may result in haemorrhage or small bowel injury with resultant fistulae.

APPENDICITIS IN PREGNANCY

Surgery is often delayed in pregnancy for fear of an unnecessary laparotomy inducing a miscarriage or premature labour. However, it is the intra-abdominal inflammatory process itself rather than the surgery, whether open or laparoscopic, that will most frequently precipitate uterine contractions. Early surgical intervention is therefore indicated. In late pregnancy the caecum and appendix will be displaced upwards by the gravid uterus, and this can cause diagnostic confusion. It should also be remembered that in late pregnancy an incision for appendicectomy will need to be made higher on the abdominal wall.

AVOIDANCE OF POSTOPERATIVE SEPTIC COMPLICATIONS

Before the advent of antibiotics, wound infections and pelvic abscesses were common after appendicectomy. Great care was taken to change instruments and gloves after contact with mucosa, which was itself then inverted with a purse-string suture. However, contamination of the pelvic peritoneum had already occurred preoperatively and the wound was inevitably contaminated as the appendix was delivered. It is now standard practice to administer prophylactic, perioperative antibiotics for all appendicular and colonic surgery, even in the absence of an infective pathology, and when a grossly inflamed or perforated appendix is found, a postoperative treatment regime of antibiotics is instigated (see Appendix II). As a result of this change in practice, infective complications following appendicectomy are now comparatively rare.

Perioperative diagnostic dilemmas

Pelvic peritonitis from another pathology, such as diverticulitis or salpingitis, will often have an appendix lying within the pus and such an appendix will show serosal inflammation. Awareness of this possibility is usually sufficient to prevent a misdiagnosis. If there is some anxiety after the removal of a relatively mildly inflamed appendix associated with pelvic pus, a useful test is to open the appendix. A pale, non-inflamed mucosa confirms the suspicion that the appendix is inflamed from without by another pathology, which must then be sought. When a small right iliac fossa incision has been utilised at open approach, extension of the wound or a separate midline laparotomy incision is often necessary for this exploration.

During an open appendicectomy an entirely normal appendix may be encountered; however, it should be removed to prevent future diagnostic difficulties in a patient with an 'appendicectomy' scar. In the absence of peritonitis, the original incision is adequate for a limited laparotomy and ileal loops should be delivered and mesenteric adenitis, a Meckel's diverticulum or terminal ileal Crohn's disease (see Chapter 23) may be apparent. The right ovary and Fallopian tube are also accessible for examination. This is, however, a situation where the laparoscopic approach has advantages.

Occasionally, an unexpected finding of a caecal carcinoma is made and a radical right hemicolectomy should be undertaken. An inflammatory mass in the right iliac fossa, from an inflamed or perforated caecal diverticulum, also requires a right hemicolectomy, which should be a radical dissection if a carcinoma cannot be excluded.

An *appendicular tumour* is occasionally encountered, and may coexist with an acute appendicitis, distal to where the tumour has obstructed the lumen. The commonest of these is a carcinoid, and if a tumour is less than 2 cm in diameter and well clear of the base, a simple appendicectomy is still appropriate. Larger or more proximal tumours require a formal right hemicolectomy, as malignant carcinoids and adenocarcinoma can both arise in the appendix.[5] A true mucocoele of the appendix is occasionally encountered and represents a non-inflamed, obstructed appendix filled with mucus. A mucinous cystadenoma of the appendix is a separate entity. It must not be ruptured during the appendicectomy as rupture may result in peritoneal contamination with subsequent pseudomyxoma peritonei (see Chapter 16). If the tumour has already ruptured or ruptures during surgery, follow-up should be arranged at a specialised centre, as early surgical treatment of the disseminated intraperitoneal pseudomyxoma will be more successful than treatment delayed until there is clinical evidence of the established syndrome.

SMALL BOWEL RESECTIONS

A small bowel resection may be indicated for a non-viable segment that has been damaged by trauma or ischaemia. Alternatively, the bowel wall may be involved in an inflammatory or malignant process. The radicality of a resection must be tailored to the pathology. For example, if only the antimesenteric border of small bowel is involved in benign pathology, a limited '**V**' resection will suffice (Figure 22.7a). The advantages of this include an intact strip of bowel at the mesenteric border, with no ligation of mesenteric vessels required, and the angulation after closure of the defect protects the suture line from forming adhesions with other peritoneal surfaces. This form of resection may be suitable for a strangulated Richter's hernia or excision of a Meckel's diverticulum, although a chance finding of the latter is now considered better ignored. It may also be suitable for the palliative excision of a malignant peritoneal deposit on the small bowel that is narrowing the lumen.

More frequently, the whole circumference of the small bowel must be excised and even when this is only a few centimetres in length, a **V** of mesentery must also be removed (Figure 22.7b). Division of the mesentery is most simply carried out by clamping it with a succession of artery forceps and cutting with scissors. The vascular pattern of the mesentery can be displayed by means of transillumination with a bright light. Windows can then be made through the avascular areas between the vessels, and the artery forceps applied to the tissue between the windows. The tissue held in the forceps is then ligated. The temptation to include a large bulk of

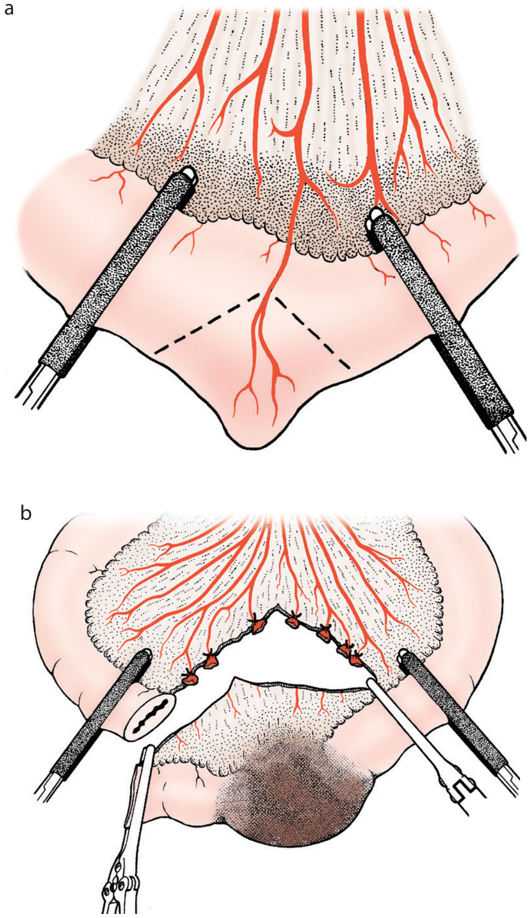

Figure 22.7 *(a) A limited V resection, which leaves the mesenteric border intact, is sometimes appropriate. (b) More often, a full circumferential resection is required associated with excision of a V of mesentery.*

mesentery in each clip should be resisted, as this nearly always results in tearing and bleeding as the ligature is tightened. When a curable malignancy of the small bowel is suspected, the **V** of mesentery removed should give the maximum lymphadenectomy without damage to the main superior mesenteric vessels.

The technical details of a bowel resection and an end-to-end anastomosis are described in more detail in Chapter 14.

FORMATION OF STOMAS

An enterocutaneous stoma is a controlled iatrogenic fistula.[6] A stoma may be fashioned as an alternative outlet to the gastrointestinal tract after excision of all distal bowel or when restoration of continuity after a resection is contraindicated (Figure 22.8). Stomas are also used as a temporary or permanent diversion of the faecal stream from distal pathology or a healing anastomosis. A temporary stoma is commonly a loop stoma that can be closed without a major laparotomy when it is no longer required. An end stoma is preferable when permanence is anticipated. A loop stoma may be left as a permanent stoma, but is more prone to complications. An *end stoma* has a single opening into the proximal bowel, and the epithelial continuity is between the skin and the whole circumference of the bowel mucosa (see Figures 22.9 and 22.11). A *loop stoma* is formed by an enterotomy on the antimesenteric border of a loop of bowel that has its continuity maintained by an intact mesenteric border. There are two openings, one into the proximal bowel and one into the defunctioned distal bowel. The epithelial continuity is between the skin and the mucosa around the edge of the enterotomy (see Figures 22.10 and 22.12).

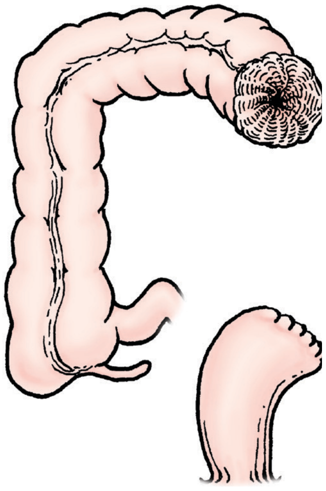

Figure 22.8 *A terminal colostomy. An end stoma has been formed and the rectum has been closed and left* in situ. *This is a satisfactory solution when there is no distal obstruction. When there is a distal obstruction, either a loop stoma should be formed or the distal end brought out as a separate mucous fistula.*

Colostomies and ileostomies are the common enteral stomas. Colostomy effluent is 'faecal' and intermittent. A sigmoid colostomy may only empty once daily with formed stool and is the easiest to manage, whereas an ileostomy may empty continually. Ileostomy effluent is thickened small bowel contents, and patients often prefer this as it is 'non-faeculent' and usually less malodorous. However, dehydration may be a problem, especially in elderly patients, in the early weeks when effluent volumes are highest. A transverse colostomy is the least popular stoma as it produces a large volume of soft offensive faecal effluent. It does, however, have a useful role as a temporary defunctioning loop stoma. Good stoma management is essential if the patient's preoperative quality of life is to be regained. The expertise of stoma nurse specialists, together with advances in appliances, have greatly reduced the problems of leakage and skin excoriation. The first essential, however, is for the surgeon to site the stoma optimally and to fashion it correctly. If at all possible, the preferred site for a stoma should be marked preoperatively by the stoma therapist in conjunction with the patient. An apparently ideal site in a patient on the operating table may be buried in a skin crease when he or she sits, or be out of sight and dependent on the under-surface of a protuberant abdomen when standing. The stoma should be through an area of smooth flat skin in order that a good seal with an appliance can be achieved. The vicinity of the umbilicus and abdominal scars should therefore be avoided.

A stoma is usually brought out through the rectus sheath a few centimetres either above or below the umbilicus. More lateral stomas were thought to be associated with a higher incidence of incisional herniae, but this is uncertain. A disc of skin and subcutaneous fat is excised. It is inadvisable to bring a stoma out through a wound as the incidence of wound infection, parastomal herniation and problems with appliance fixation to irregular scarred skin are all increased.

Left iliac fossa end colostomy

This stoma is formed after a resection that leaves no distal bowel to which an anastomosis can be made or when a restorative procedure is contraindicated. It is, therefore, the final step in an abdominoperineal resection or a Hartmann's procedure. An end left iliac fossa colostomy may also be used as a permanent diversion of a rectum irretrievably damaged by tumour, inflammation or trauma, and as a final solution for faecal incontinence or a rectovaginal fistula. The rectum is closed and left *in situ* (Figure 22.8). However, this is an unsuitable operation if there is distal obstruction, or the prediction that this will occur later, as the rectal stump may distend with mucus and the closure disrupt with resultant peritonitis. Instead, either a loop stoma should be used or, in addition to the end colostomy, the distal defunctioned end should be brought out as an additional stoma, which is described as a *mucous fistula*.

Adequate length is essential in creating the stoma or retraction will occur, and allowance must be made, particularly in fat patients, for the anterior abdominal wall protuberance that will occur when standing. Postoperative distension from ileus will also increase any tension. If the bowel division has been high in the descending colon, mobilisation of the colon by incision of the peritoneum lateral to the bowel will increase the length of colon available, and can be extended to a full mobilisation of the splenic flexure if necessary.

The optimal site on the colon for the stoma is chosen and the bowel divided with a mechanical linear stapling device. This has the advantages of closing the distal end definitively and producing a temporarily sealed proximal end for delivery through the abdominal wall without the extra bulk of a clamp. (If such a device is not available, the distal end is closed with sutures and a small clamp used to seal the proximal bowel.)

The disc of skin and subcutaneous fat is excised at the chosen stoma site and a horizontal or vertical incision is made through the anterior layer of the rectus sheath. The rectus muscle is split and the incision extended through the posterior sheath and the parietal peritoneum. The size of the opening is difficult to judge; it should be snug, but not tight, around the bowel. Too small an abdominal fascia incision produces a dusky oedematous stoma, while too large an incision predisposes to a parastomal hernia. It is easy to damage the inferior epigastric artery within the rectus muscle. At open surgery the pulsations can be palpated from within so that an incision through the vessel can be avoided. If cut, the ends retract and are difficult to locate. When injury occurs and there is a separate laparotomy incision, deep suture ligations placed from within, a few centimetres above and below the stoma incision, will include the severed vessel, and is the easiest method of control.

A Babcock forceps is introduced through the stoma incision to hold the proximal bowel end and guide it gently through the abdominal wall to the skin. The main incision, or laparoscopic ports, is/are then closed before the stoma is opened. The few millimetres of colon that are crushed in the clamp or held with staples are excised. Bleeding points may have to be coagulated, and the free edge of bowel is then sutured to the skin around the defect with fine interrupted absorbable sutures. Each bite should include the full thickness of bowel wall and a bite of skin, although it is important to deliver the needle close to the skin edge (Figure 22.9).

If no resection is planned, the surgeon will wish to avoid a major laparotomy. It may be possible to perform a *trephine stoma*, in which a loop of mobile sigmoid colon is delivered through the definitive incision for the stoma. This is not always possible, however, and it may be dangerous if there is tension due to inadequate mobilisation. The colon is delivered outside the wound, divided and the sealed distal end replaced. It is imperative that at this stage the surgeon is sure which end is the proximal bowel and which the distal bowel. When access is too limited for certainty, insufflation of the rectum with air from below will confirm the distal limb. The limited division of the sigmoid mesentery, to allow sufficient separation of the ends without devascularisation, is also more difficult with a trephine technique. Injury to the inferior epigastric vessels is both more difficult to avoid and more difficult to treat when there is no separate abdominal incision. An increasingly popular alternative to the simple trephine stoma technique is to combine it with a laparoscopic mobilisation of the sigmoid loop. The mobilisation is completed and the pneumoperitoneum released, while the sigmoid loop or sealed end is held just under the site of the stoma by an instrument retained within a port site. Identification and delivery of the colon through the small trephine incision are thus much easier.

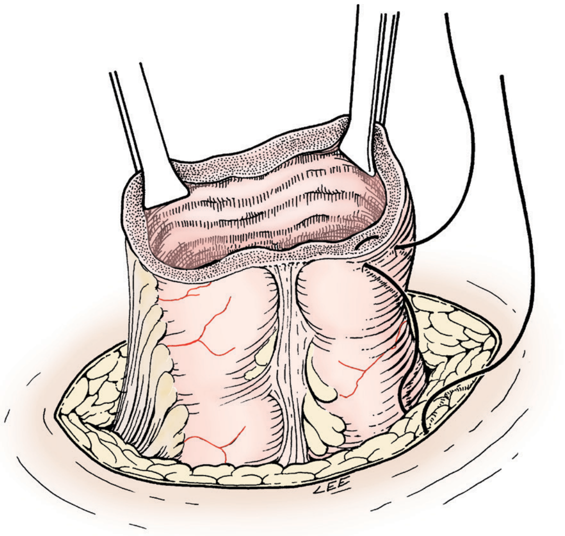

Figure 22.9 *An end colostomy. The closed end of colon has been brought through the abdominal wall and trimmed. Skin mucosal apposition is then achieved with interrupted absorbable sutures. This is illustrated here with a suture passed extramucosally in the bowel and subcuticularly in the skin; this may be a superior refinement to the simpler suture described in the text.*

Where laparoscopic facilities are unavailable and a simple trephine technique is not straightforward, a small laparotomy to mobilise the sigmoid is safer. A lower abdominal midline incision is the approach usually recommended, but a low left iliac fossa oblique muscle-cutting incision has the advantage of giving better access to the peritoneum lateral to the sigmoid colon. This incision can be placed so that it will lie outside the fixation of the appliance. It must be below, lateral and at a sufficient distance from the skin mark of the proposed site of the stoma.

Left iliac fossa loop colostomy

A left iliac fossa loop colostomy is the appropriate stoma when there is a rectosigmoid obstruction and no resection is planned, as it can also decompress the distal colon immediately above the obstruction. If, however, a later resection is planned, a more proximal colonic stoma may be preferable. The pelvic colon is mobilised as for the formation of an end colostomy. The bowel is not divided but brought out as a loop in a similar manner to the fashioning of a transverse loop colostomy.

Transverse loop colostomy

A transverse loop colostomy is a temporary stoma and was traditionally the standard emergency treatment of a left colon obstruction. It may still have a place in this situation (as discussed in Chapter 23), but a primary resection or colonic stent, if feasible, is now the preferred option. The defunctioning loop colostomy is most often indicated as a temporary diversion to protect a left colon anastomosis. Coloanal anastomoses are particularly vulnerable to anastomotic leakage and some surgeons routinely defunction with a loop stoma. Surgeons were divided in their preference for either a loop transverse colostomy or a loop ileostomy as a temporary measure, but most now favour an ileostomy in most circumstances. The colostomy is less pleasant for the patient to manage and is probably associated with more wound infections and incisional herniae after closure. These disadvantages may be offset by a reduced likelihood of early fluid and electrolyte loss and a lower long-term risk of late adhesion obstruction. In addition, if there should be a leak, the more distal stoma may provide a better defunction of the anastomosis and reduce contamination from the leak.

A suitable site in the proximal transverse colon is selected that will reach the abdominal skin without tension. The greater omentum is separated from this portion of the colon and a pericolic window is made close to the bowel wall. An artery forceps is passed through the window to grip a soft catheter, which is guided through (Figure 22.10a). A stoma incision is then made in the same fashion as for a left iliac fossa colostomy, but in the right hypochondrium. A forceps passed through the stoma incision can grip the catheter and guide the loop of colon through the abdominal wall while it is eased through from inside (Figure 22.10b). The main incision is then closed. If a colostomy bar is to be used, it is guided through the mesenteric window by inserting one end, which has been swivelled to lie in line with the bar, into the open end of the catheter. The catheter is removed and the end of the bar swung back to right angles (Figure 22.10c). The bar is removed at about 10 days postoperatively and until then provides support to the colonic loop, preventing

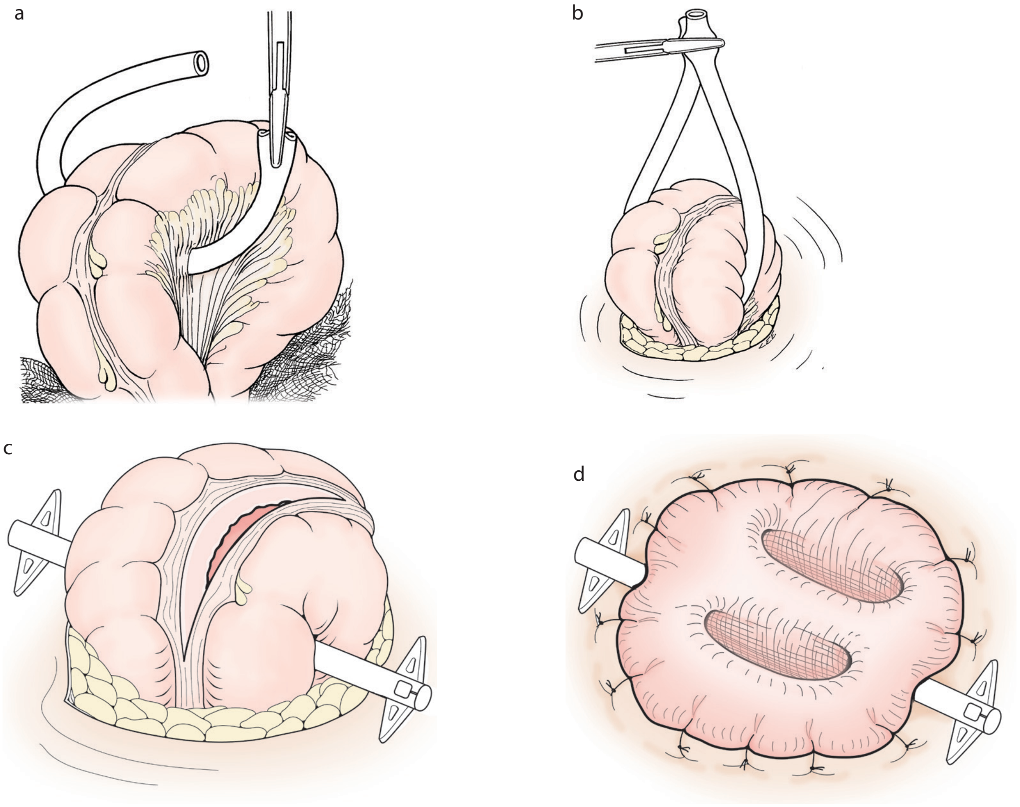

Figure 22.10 *A loop colostomy. This is illustrated with a colostomy bar, which many surgeons now reject on the grounds that if there is no tension it is of no value, and argue that it merely causes difficulty with early appliance fixation and may cause additional scarring, which could make subsequent closure more difficult. (a) An artery forceps has been passed through a mesenteric window close to the bowel and is now drawing a catheter through. (b) An artery forceps has been passed into the abdomen through the prepared stoma site and the ends of the catheter grasped. The bowel is gently delivered to the exterior. (c) The colostomy bar has been guided through the mesenteric window by its insertion into the open catheter end. A longitudinal incision is made in the colon. (d) The bowel edges are folded back to the skin edges and skin–mucosal apposition is achieved with interrupted sutures, except where the stoma bar emerges.*

retraction. Severe tension will, however, result in the bar ulcerating through the bridge of intact bowel wall and will not prevent retraction in this situation. The main abdominal wound is now closed. The stoma is then opened and sutured to ensure skin–mucosal apposition and healing without stenosis. A longitudinal incision along a taenia can be made with scalpel and scissors or with diathermy, with care being taken to avoid injury to the opposite wall of the bowel (Figure 22.10c). The bowel is then opened and the cut edge of bowel apposed to the skin edges of the colostomy incision with interrupted absorbable sutures in the same fashion as when suturing an end colostomy. Skin mucosal apposition is only deficient where the stoma bar emerges (Figure 22.10d).

End ileostomy

This is the stoma created at the completion of a total colectomy. The optimal stoma site, high in the right iliac fossa, should have been marked preoperatively.

At surgery, a disc of skin is excised and an incision made through the abdominal wall as described for an end colostomy. The terminal ileal stump is then drawn through the abdominal wall in a similar manner, with care being taken to avoid rotation. There will inevitably be some mesentery drawn through with the ileum, as complete division of this from the bowel will result in an ischaemic stoma. Skin mucosal apposition is again achieved with interrupted absorbable sutures, but a 'spout' to the stoma should be created so that the more liquid stoma effluent drops into the bag, beyond the flange of the appliance. A flush ileostomy can result in excoriated skin due to leaks as the flange separates from the skin. A spout of 2–3 cm is sufficient and is fashioned from the terminal 6 cm of the bowel, which has been drawn out through the abdominal wall. The spout is created by an eversion manoeuvre, in which the first four skin–mucosal apposition sutures include a seromuscular bite of more proximal bowel wall (Figure 22.11a). Care must be taken not to include mucosa in this seromuscular bite, as it may create a fistula at the stomal edge. When placing these sutures, care must also be taken to avoid injury to the mesentery of the bowel. The mesentery often distorts the stoma initially, but after eversion it is normally no longer a problem. These four sutures are left untied until all are in place, and then, as they are tied, the stoma everts. The stoma must sometimes be gently eased into position, as complete reliance on the sutures to achieve eversion may cause them to tear through the bowel. The stoma should ideally point slightly downwards, and this can be achieved by placing the superior everting suture with its seromuscular bite 6 cm from the free edge, an inferior suture with a bite at 4 cm and two lateral sutures with bites at 5 cm. Precise measurements of the distance of these bites from the open bowel end make the creation of an optimal stoma easier. After eversion, a further skin–mucosal apposition suture is placed between each of the everting sutures (Figure 22.11b).

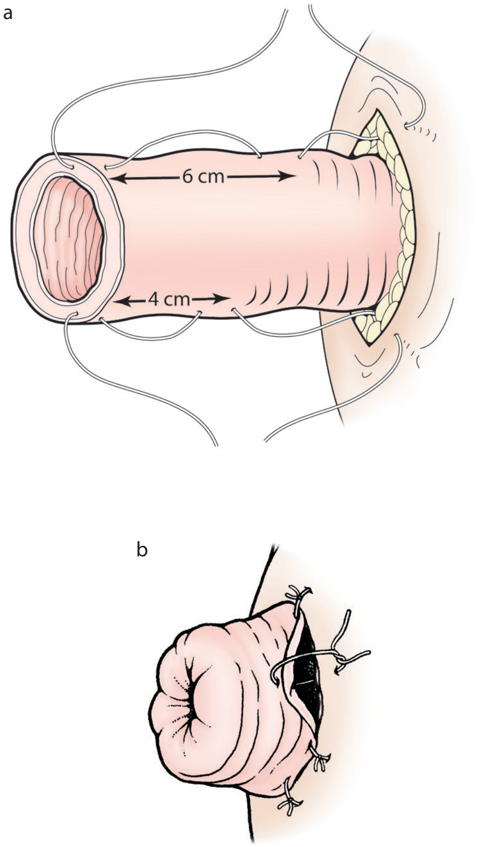

Figure 22.11 *An end ileostomy. (a) Lateral view of the stoma as the everting sutures are inserted. These sutures include a seromuscular bite of the ileal wall between the bites of skin and bowel edge. To produce a 2.5-cm spout, facing slightly downwards, these seromuscular bites should be 6 cm from the end of the ileum superiorly and 4 cm inferiorly. Laterally, they should be at 5 cm. (b) The everting sutures are tied, the spout is formed and skin–mucosal apposition is completed with additional sutures.*

Loop ileostomy

A loop ileostomy is the stoma most frequently used to defunction an empty colon in order to protect a vulnerable distal anastomosis. The stoma incision is prepared and a Babcock forceps passed through the stoma incision to hold the terminal loop of ileum and draw it gently through to the exterior. Before closure of the main laparotomy wound or laparoscopic ports, the loop is orientated so that the distal limb is inferior and three sutures are placed apposing the unopened wall of the distal loop to the skin edge (Figure 22.12a). After the main wound is closed, the stoma is opened by an incision 2–3 mm above the three sutures. The incision is extended to just over half the diameter of the distal limb. Eversion sutures are then placed superiorly and laterally, exactly as for a terminal ileostomy (Figure 22.12b), and the proximal limb of the stoma drawn out as a spout (Figure 22.12c).

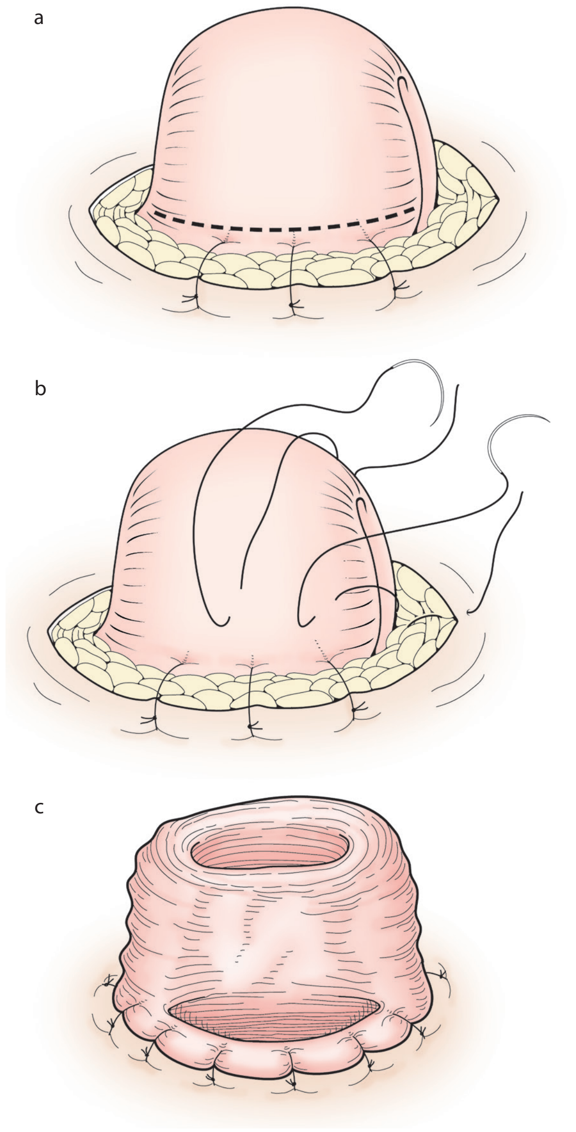

Figure 22.12 *A loop ileostomy. (a) Three sutures are placed between the skin edge and the seromuscular coat of the distal limb prior to closure of the main wound. This manoeuvre prevents any rotation of the loop and confusion as to which is the proximal and which the distal limb. (b) An incision has been made a few millimetres above the three seromuscular skin apposition sutures. The superior and the first lateral eversion sutures are in place, but untied. (c) As the sutures are tied, the stoma everts as a spout. Viewed from below, the distal bowel opening is visible, flush with the skin.*

STOMA COMPLICATIONS

Some patients have a trouble-free stoma, while others have recurrent problems that may need further surgery.

Retraction and stricture

Retraction of a stoma in the first 2 weeks is often in conjunction with separation of the skin to mucosa suture line. It is most commonly caused by excessive tension on the afferent bowel, and therefore no local operation on the stoma will be helpful. Re-laparotomy is indicated if there is cellulitis around the stoma, indicating escape of bowel contents into the abdominal wall, or if signs of peritonitis indicate escape into the peritoneal cavity. Reoperation will be difficult as a new stoma will have to be fashioned with bowel, which will be more friable to handle, and problems of tension will be increased by postoperative oedema. Fortunately, more minor degrees of early retraction can usually be managed conservatively, although a stricture may develop as healing occurs by secondary intent.

A late retraction of a colostomy, often with an associated stricture, or an ileostomy that has lost its spout can usually be corrected by a local refashioning operation. The skin immediately adjacent to the stoma is incised circumferentially and the stoma mobilised as for a stoma closure (see below) and refashioned. A re-laparotomy can be avoided unless adequate length cannot be obtained without deeper mobilisation. An intermittently retracting ileostomy can be fixed in position by linear stapling at two or three positions around the circumference. One blade of the stapler is introduced into the ileostomy and the other blade is on the outside. It is important that the linear cutting stapler is not used in error!

Conservative management of a stricture with dilation is sometimes successful, but more often, revision surgery is required. A stricture at the mucocutaneous junction, without stoma retraction, can be solved very simply by a minor operation under local anaesthesia, as minimal dissection is required. The skin is incised circumferentially just outside the stenosed orifice and the stoma is then mobilised down to the abdominal fascia. The stenosed mucocutaneous junction is trimmed from the end of the stoma and a fresh apposition of skin and bowel secured with interrupted sutures. At this stage, the surgeon often realises that the incision around the stenosed stoma has removed too large a disc of skin.

Prolapse

Prolapse of an end colostomy can be dealt with locally by a circumferential skin incision. After minimal dissection the redundant bowel is drawn out and amputated. The new end is sewn to the skin edges. Unfortunately, recurrence is common. A prolapse is sometimes associated with an incisional hernia and is then best managed by re-siting of the stoma (see below). Colostomy prolapse is more common in loop stomas and can usually be managed conservatively until closure can be safely undertaken. If closure is not an option, full mobilisation of the stoma will allow division of the loop. The distal end, which is often the end that is prolapsing, is then closed and dropped back into the abdomen. Proximal redundant bowel can be excised before resuturing the bowel to the skin edges. This is, of course, only an option when there is no distal obstruction.

Prolapsing end ileostomies are uncommon and any local excision procedure is likely to offer a temporary solution only because of the mobility of the small bowel. To prevent prolapse, the bowel adjacent to the stoma must be fixed to the parietal peritoneum over a distance of about 10 cm with non-absorbable sutures. The old technique of extraperitoneal routing of an ileostomy to obliterate the lateral space produced a similar fixation of the terminal ileum.

Parastomal herniae

Parastomal herniae are difficult to treat but strangulation, although possible, is fortunately uncommon. Surgeons are therefore often reluctant to advise any revisional surgery, especially if the hernia is easily reducible. Patients, however, are often troubled with both the difficulty in securing the appliance and the prominence of the stoma appliance showing through their clothes when it is secured to the summit of a protruding hernia. Patients may also complain of abdominal wall discomfort on exertion or colic from small bowel loops within the sac. Occasionally, a specially fitted corset will be of value.

Local mobilisation of the stoma and excision of the hernial sac, followed by one or more sutures placed to narrow the abdominal wall opening, and, finally, resuturing of the bowel end to the skin is simple, but usually fails. The addition of mesh reinforcement has traditionally been avoided because of concern over mesh infection, but this risk has probably been overestimated.[7] The most satisfactory alternative is often to reopen the abdomen and re-site the stoma through a separate area of abdominal wall. The stoma and the associated hernia can be dissected from both within and without, the hernial sac excised and the old stretched stoma defect closed completely.

Re-siting may be impractical if the abdomen is extensively scarred or if there is insufficient length of bowel to reach another abdominal site. A third alternative is to approach the parastomal hernia from outside, but through an incision placed well lateral to the stoma itself.[8] Incisions on both sides of the stoma may improve access to the sac for dissection, reduction and closure. The stoma is excluded from the operative field with a skin adhesive covering and the skin–mucosal apposition of the stoma is left undisturbed. Contamination of the abdominal wall defect can thus be avoided and a mesh may be used to encircle the bowel at the level of the fascia. Laparoscopic repair can also avoid contamination. The use of collagen meshes, although expensive, reduces the concern over mesh infection. Prophylactic mesh insertion when a stoma is created does seem to reduce the incidence of parastomal herniation.[9]

CLOSURE OF LOOP STOMAS

A temporary stoma, which has protected an anastomosis, may be closed as soon as the anastomosis is soundly healed. Early closure, at around 2 weeks, is practised by some surgeons but is technically more difficult at this stage. A delay of 6–8 weeks allows the stoma to mature and the planes around the stoma to become better defined. The additional wait will also allow the patient to regain nutritional and immunological status after a major operation, and will also reduce the risk of thromboembolic complications. However, the patient has to learn to manage the stoma in order to return home.

An elliptical incision allows linear closure of the skin (Figure 22.13a), but some surgeons prefer a circular skin incision that cicatrices to a circular scar. The skin incision is deepened into subcutaneous fat and the bowel wall identified. Two artery forceps, placed on the skin to be excised, provide useful counter-retraction while the assistant retracts the skin and subcutaneous fat. The plane is followed between the bowel and the subcutaneous fat and then between the bowel and the abdominal wall until the peritoneal cavity is reached. The assistant retracts progressively deeper as the dissection continues. The correct plane is easier to identify adjacent to the bowel than adjacent to the mesentery, and the plane will be particularly difficult around the scarring from a colostomy bar, if a bar was used. If the surgeon dissects in one area until the plane becomes difficult, and then moves to another area, again until difficulty is encountered, generally on returning to the previous area the dissection is now easier as mobility has increased. Some difficulty is occasionally encountered deep in the abdominal wall dissection, as dissection may enter an extraperitoneal plane rather than entering the peritoneum. After the peritoneal cavity is entered, a finger, introduced and swept around the fascial defect, can identify further bands to be divided. Adhesions can be broken down with the finger, but great care must be taken not to tear a loop of adherent small bowel. The stoma can now be lifted further out into the wound, and the dissection to free the stoma has also prepared the abdominal wall for a satisfactory closure of the fascia. If extreme difficulty is encountered, or damage has occurred to adjacent bowel, the surgeon must extend the wound to convert to a mini-laparotomy. Alternatively, a separate midline incision is made.

A *colostomy stoma* is prepared for closure by excision of the mucocutaneous junction (Figure 22.13b). Difficulties are more often encountered if too little rather than too much is trimmed, as the bowel wall is still distorted and thickened. Haemostasis may be required, and the colonic wall defect is then closed transversely (Figure 22.13c) with interrupted extramucosal sutures as described in Chapter 14 (p. XXX).

An *ileostomy stoma* cannot be closed until the eversion has been reversed. After full mobilisation of the stoma as described above, the skin adherent to the eversion is incised to gain access to the plane between serosal surfaces, which is then developed until the alignment of the original

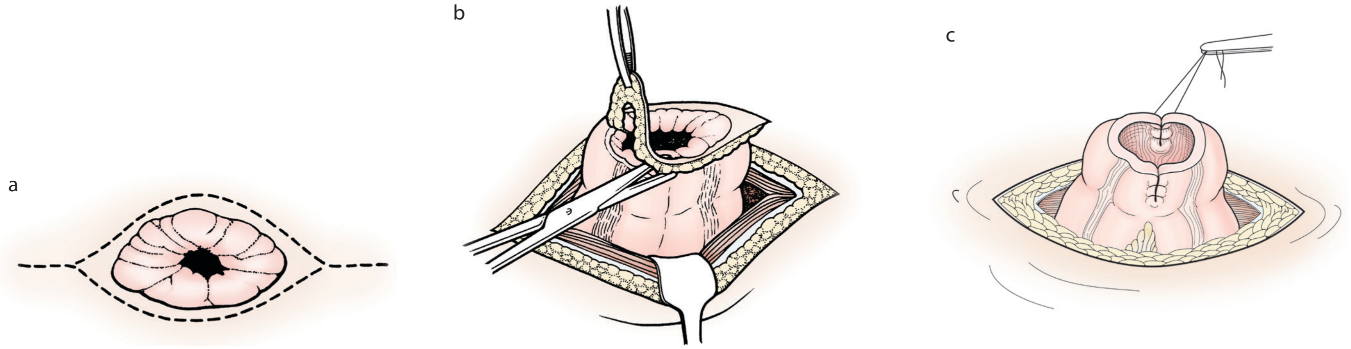

Figure 22.13 *Closure of a loop stoma. (a) Elliptical skin incision. (b) After full mobilisation of the stoma, the mucocutaneous junction of the colostomy is excised. (c) The bowel is then closed transversely.*

enterotomy has been restored (Figure 22.14). The remaining mucocutaneous junction is excised and the defect closed as for a colostomy. It is easy to damage the bowel wall where the plane is first developed for reversing the eversion. A minor injury can simply be sutured, but if it is more significant, a formal resection of a short segment of small bowel and reanastomosis is safer, and this can be performed without enlarging the incision.

An alternative to an end-to-end, partial circumferential, sutured anastomosis is a side-to-side stapled anastomosis. This is more suitable for closure of a loop ileostomy than for a colostomy. The initial mobilisation of the stoma and trimming of the mucocutaneous junction are identical. A linear cutting stapling device is then introduced so that one blade lies within the efferent bowel and one in the afferent bowel. A finger is swept between the blades from one side to the other, before the instrument is closed, to displace the mesentery out of the staple line. The device is fired to create the anastomosis. The device is then withdrawn, re-loaded and fired again across the two open bowel ends to close them.

After completion of the bowel closure, the loop is dropped back into the peritoneal cavity. If replacement is difficult despite good relaxation, a small lateral release of the abdominal fascia allows replacement without endangering the suture line by excessive pressure. Incisional herniae are common through these wounds, and meticulous abdominal wall closure to include the anterior rectus sheath fascia is essential. This is difficult through the small skin incision and is easiest to achieve by placing three or four interrupted sutures, which are left untied until all sutures are in place. If an elliptical incision has been made, the wound may be closed primarily with interrupted or even subcuticular sutures. A drain to the subcutaneous fat has advantages in the obese patient. A pressure dressing to the wound may also decrease the incidence of wound infection, by reducing the formation of a contaminated seroma or haematoma in the subcutaneous fat. Circular incisions are usually left open to heal by secondary intention, but a purse-string subcuticular suture may be used to reduce the size of the wound and subsequent scar.

Closure of an end stoma requires identification of the distal bowel end. If this has been secured just beneath the stoma or brought out as an adjacent mucous fistula, a dissection followed by an anastomosis may be possible through a small local incision. More often, unfortunately, the distal bowel can only be identified from within. If laparoscopy is unavailable, this will often require a full laparotomy.

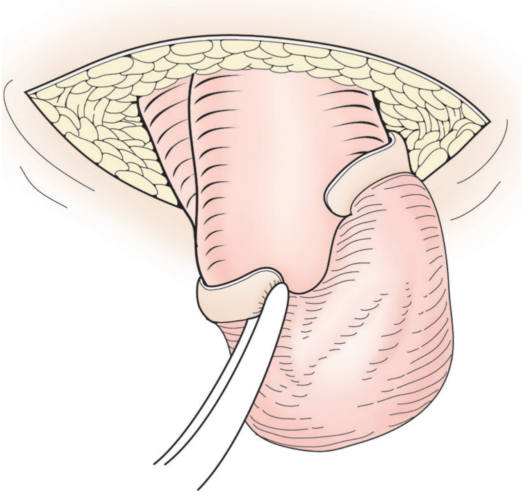

Figure 22.14 *Excision of the mucocutaneous junction of a loop ileostomy is combined with dissection in the plane between the serosal surfaces of the everted spout to allow the eversion to be reversed before the bowel is closed.*

Long-term complications of temporary stomas include incisional herniae, which are more common after the closure of a colostomy, and adhesion obstruction, which may be more common after a previous ileostomy.

THE USE OF BOWEL IN RECONSTRUCTION

Small bowel

The mobility of the small bowel, combined with its excellent blood supply, renders it ideal for gastrointestinal, biliary and urinary reconstruction.

POUCHES

The simplest pouch is a fold back of the terminal ileum after a proctocolectomy to create a **J**-shaped reservoir or 'neorectum' for anastomosis to the anus. This can be achieved very simply with a linear stapling device (see Figure 23.7, p. 423), which is reloaded after firing and reinserted to anastomose a further segment until a 15–20-cm **J**-pouch has been created (see also the stapling section of Chapter 14 and ileoanal pouches in Chapter 23). The pouch can also be constructed by hand, using continuous extramucosal sutures. **W**- and **S**-shaped pouches have been used, but were generally abandoned as they were more time-consuming to construct, and the **S**-pouch had inferior function to the simpler **J**-pouch.

ROUX-EN-Y LOOP

This technique provides a long conduit that is empty of gastrointestinal contents and will reach further than a simple loop of jejunum. Its construction also excludes bile and gastrointestinal contents from the apical anastomosis, provided that the conduit is of adequate length (Figure 22.15). The first loop of jejunum is used, and the jejunum is divided about 10–15 cm from the duodenojejunal flexure. The divided distal end forms the apex of the conduit and some mesenteric division and sacrifice of jejunal vessels will be required to create adequate length. Visualisation with back-lighting is essential to ensure preservation of blood supply via intact arterial arcades. The proximal end is then anastomosed end-to-side some 40–70 cm down the distal limb. A Roux loop can be used to bypass an inoperable pyloric malignant obstruction or to form a conduit into the gastrointestinal tract for the internal drainage of a fistula (see Figure 15.6, p. 253). Standard Roux loops and adaptations of them are also used extensively in the reconstruction required to restore upper gastrointestinal continuity and biliary drainage after radical resections for malignancy. They are also utilised for repair of biliary strictures and in bariatric surgery. These operations are described in more detail in the upper gastrointestinal and pancreaticobiliary chapters (Chapters 17 to 20).

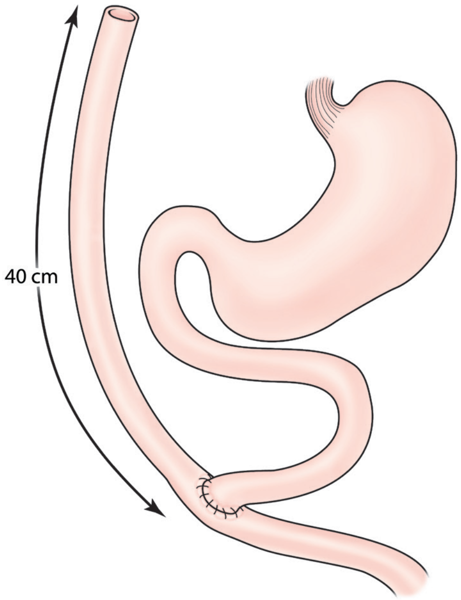

Figure 22.15 *A Roux loop is created by division of the bowel and the reanastomosis of the proximal end to the side of the distal limb. This anastomosis must be at least 40 cm, and preferably 70 cm, along the distal limb to prevent reflux of luminal contents from reaching the apical anastomosis.*

ISOLATED SEGMENT OF SMALL BOWEL

A segment of small bowel may be isolated on its blood supply and the small bowel continuity restored. An ileal segment is most commonly used as a urothelial substitute and a jejunal segment is occasionally employed as an interposition segment in the upper gastrointestinal tract. The ileal conduit, into which the ureters are implanted, is the standard urinary diversion after a total cystectomy. The ileal conduit is then brought out as a urinary stoma (see Figure 26.15, p. 494) or occasionally anastomosed to the urethra as a continent bladder reconstruction. An isolated ileal segment can also be opened and used to augment a contracted bladder (see Chapter 26). Where microvascular skills are available, a free jejunal loop can be used for pharangeal reconstruction (see Chapter 10).

Large bowel

POUCHES

The formation of a short colonic **J**-pouch after a low anterior resection provides a coloanal anastomosis with superior function to a straight anastomosis. The pouch is created with a linear stapling device in a similar manner to an ileal pouch. Only a single firing of a 5-cm stapler is required. The colonic mesentery is thicker than the ileal mesentry and it may be more difficult to rotate out of the anastomotic line (see Figure 22.32).

ISOLATED SEGMENTS OF LARGE BOWEL

Oesophageal replacement on a middle colic pedicle

Small bowel, although ideal for reconstruction within the abdomen, is not so suitable for replacement of the intrathoracic oesophagus and can seldom provide adequate length. The stomach is most commonly used following resections for cancer, but an alternative is the ascending colon mobilised as an isoperistaltic loop, based on the middle colic vessels (Figure 22.16). The isolated colon on its vascular pedicle may be brought up to the cervical oesophagus by the anatomical posterior route or, alternatively, either retrosternally or subcutaneously, as discussed in Chapter 17. Other colonic segments may be used, but a left colon conduit will only reach if it lies in an antiperistaltic direction, and function will be poor.

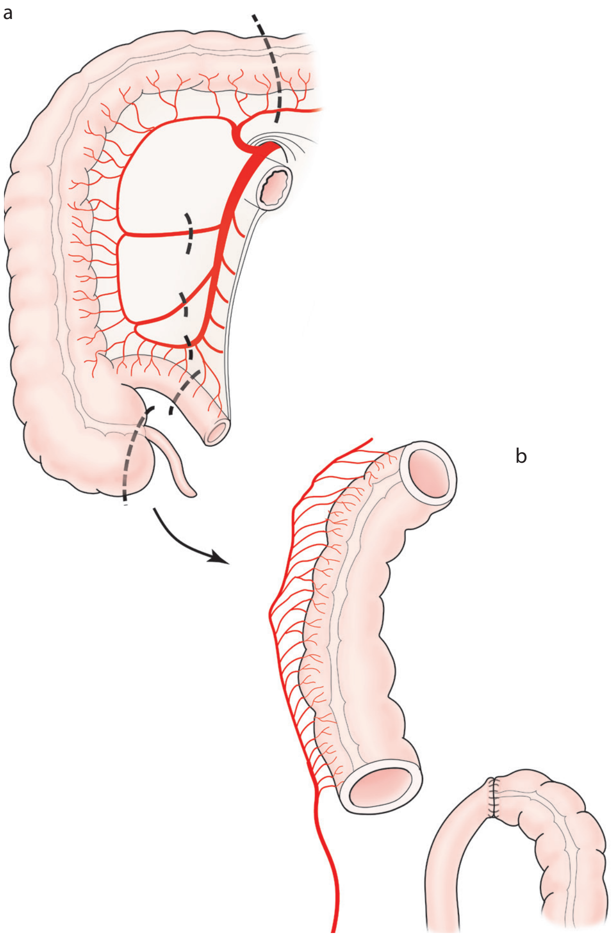

Figure 22.16 *(a) The anastomotic arcades close to the bowel wall allow isolation of the ascending colon and the hepatic flexure perfused by the middle colic artery. The right colic and ileocolic vessels are divided. The terminal ileum is divided and the appendix removed (alternatively, the caecum is transected to remove both the appendix and the ileocaecal valve). (b) The caecum is swung up and an iso-peristaltic conduit, which will reach the neck, has been created. The caecum or terminal ileum can then be anastomosed to the cervical oesophagus and the divided transverse colon to the stomach. Intestinal continuity is restored with an ileocolic anastomosis.*

Rectal replacement on an ileocolic pedicle

This segment, which includes a few centimetres of terminal ileum, the caecum and the ileocaecal valve, has a good blood supply from the ileocolic vessels. Intestinal continuity is restored by an ileocolic anastomosis. The isolated segment has good mobility and can be rotated over into the left iliac fossa and pelvis as a caecal interposition when, after a distal large bowel resection, the divided left colon will not reach the pelvic floor. The ileal end of the segment is anastomosed to the descending colon and the caecum is anastomosed to the rectal stump. The place for this technique is, however, limited.

Urothelial substitution

The colon has proved generally less suitable as a urothelial substitute, partly because there is a long-term risk of neoplasia in colonic mucosa exposed to urine.

RADICAL COLONIC RESECTIONS

Small bowel resections are almost exclusively for benign pathology, whereas resections of the large bowel are more frequently undertaken for malignancy. Adenocarcinoma of the colon (as discussed in Chapter 16) is a malignancy which at presentation often has lymph node involvement in the absence of distant metastases. It is, therefore, still potentially curable if the primary tumour is excised *en bloc* with its lymphatic drainage. As the lymphatic drainage follows the arterial supply, radical lymphadenectomy is planned on the arterial anatomy of the colonic mesentery (see Figure 22.2). The ascending and descending colon and the rectum have retroperitoneal mesenteries, and large bowel resections are therefore predominantly concerned with accurate dissection to isolate these mesenteries.

The length of bowel to be excised is determined by considerations of reconstruction. The ends must reach for a tension-free anastomosis and the blood supply of the ends must be adequate for healing. Radical lymphadenectomy inevitably compromises the vascularity of a longer segment of bowel than that which would have to be excised to clear a tumour, which has minimal ability to spread intramurally. The extent of the lymphadenectomy is thus the important determinant of the length of colon that has to be excised.

The anastomosis after a large bowel resection may be more technically challenging than a small bowel anastomosis because of poor access, but the same general anastomotic principles apply. The blood supply is more critical in the colon than the small bowel, and is one reason why anastomoses are more vulnerable. Solid intraluminal material with a high bacterial content is an additional adverse factor. An ileocolic anastomosis is safer than an anastomosis of colon to colon, and a coloanal anastomosis is the most vulnerable of all. Preoperative mechanical emptying of the colon (except in obstruction) used to be recommended for all left-sided resections, but in recent years has been reported to be unnecessary.[10] Perioperative antibiotics should be given to reduce septic complications in all colonic resections (see Appendix II).

Radical colonic resections can be undertaken either by the classical open approaches or laparoscopically. Any short-term benefit of the latter method in terms of a faster postoperative recovery is obviously negated if the surgeon is unable to offer an equally secure anastomosis after an equally precise and radical removal of the malignancy. The choice of method will depend on factors such as the position of the tumour, the build of the patient, the relative skills of the surgeon in the two methods and the availability of laparoscopic equipment.

A small tumour can be difficult to locate at laparoscopy, and if laparoscopic surgery is planned, then the colon should have been tattooed just distal to the tumour at endoscopy.

The operations all commence with an assessment of the primary tumour and a general exploration for previously undetected tumour spread or other pathology. Every operation must then be tailored to the vascular anatomy and the length and mobility of the colon in the individual patient. The exact position of the tumour may dictate adaptations of a standard resection. A more radical excision may be justified for a locally advanced but still potentially curable tumour, and loops of adherent small bowel or other organs may have to be excised *en bloc*. Conversely, a less radical lymphadenectomy may be a justifiable alternative in the presence of inoperable liver secondaries or in a frail elderly patient. In these instances the primary lesion can be excised with only a limited wedge of mesentery, thus minimising the dissection for mobilisation. All modified resections are, however, based on the standard resections described below.

Right hemicolectomy

A radical right hemicolectomy is performed for malignant tumours of the caecum, ascending colon and hepatic flexure, and also for the less common malignant tumours of the appendix or terminal ileum. Radical lymphadenectomy involves the excision of the lymphatic drainage from the tumour to the proximal mesenteric nodes, which are around the origin of the ileocolic and right colic arteries from the superior mesenteric artery. Ligation of these arteries at their origin determines the length of colon to be excised (Figure 22.17). The right colon must be mobilised with its retroperitoneal 'mesentery' from the right paracolic gutter, as described in Chapter 14. The white line on the peritoneum lateral to the right colon is a guide for entering the plane between this mesentery and the truly retroperitoneal structures.

OPEN RIGHT HEMICOLECTOMY

Most surgeons favour a midline incision. Good intraperitoneal access is obtained by retraction and small bowel exclusion from the operative field (see Chapter 14). The peritoneum is incised along the white line lateral to the right colon and extended as shown in Figure 22.18. The areolar plane is identified by retraction of the ascending colon forwards and medially. This avascular plane behind the colon is followed medially by sharp dissection, allowing the gonadal vessels and ureter to fall back into place. An injured gonadal vessel may have to be ligated; generally, no adverse effects on the testis result from ligation within the abdomen. The ureter must be identified and protected from injury. Inadvertent ureteric injury or the need to sacrifice a ureter on oncological grounds is discussed in Chapter 26. As the dissection is continued medially, the second part of the duodenum and the anterior surface of the head of the pancreas are exposed, and care must be taken to prevent tears to small delicate vessels in this area. If bleeding does occur, it is best treated initially by the application of an adrenaline-soaked swab, which is left undisturbed for 5 minutes. Continuing bleeding should be

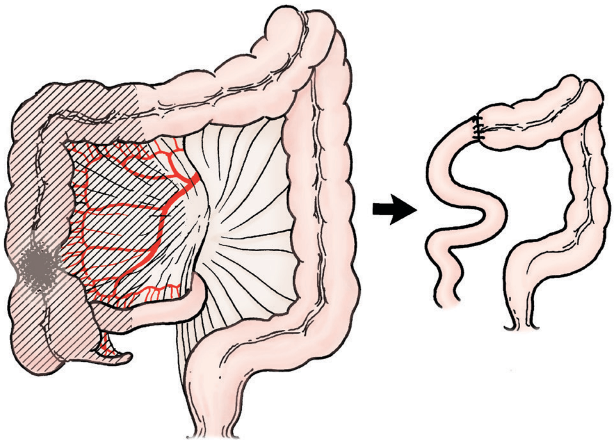

Figure 22.17 *A right hemicolectomy. The right colic and ileocolic vessels are divided and the tumour excised* en bloc *with the lymphatic drainage alongside these arteries. The bowel supplied by these arteries is excised and continuity restored by an ileocolic anastomosis to the proximal transverse colon. A right hemicolectomy for a caecal pole tumour should include in the resection specimen the lymphatic channels alongside the terminal arcade of the mesenteric root; a longer segment of terminal ileum may have to be sacrificed.*

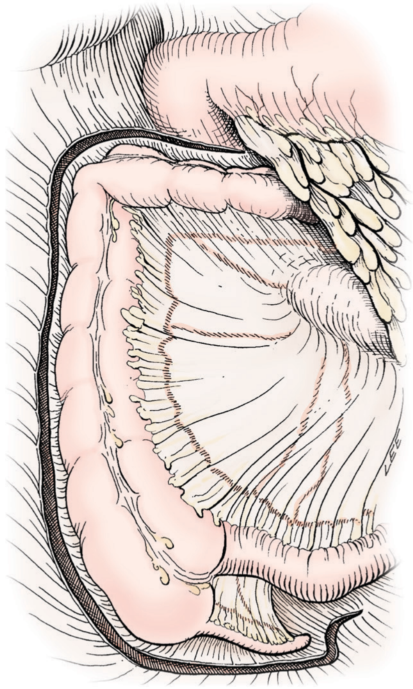

Figure 22.18 *In an open right hemicolectomy the lateral peritoneal incision is the first step in mobilising the right colon with its retroperitoneal mesentery. Note the relationship to the second part of the duodenum.*

controlled by a fine suture, as the application of artery forceps or diathermy may cause further pancreatic trauma. The superior mesenteric artery and vein are identifiable just below the pancreas, at the root of the mesentery.

The line of the mesenteric transection is lateral to the main trunks of the superior mesenteric vessels, which must be preserved. The ileocaecal valve, 15–25 cm of terminal ileum and the ileocolic vascular arcade with the associated lymphatic drainage are included in the resected specimen. The superior mesenteric, right colic and ileocolic arteries are often visible in the mobilised mesentery but, if not, their position can be confirmed by palpation. The ileocolic and right colic arteries are ligated and divided close to their origin, but with care being taken to avoid damage to the superior mesenteric vein, which lies along the right side of the superior mesenteric artery throughout this dissection. An elegant dissection, which guarantees a radical lymphadenectomy, involves the initial identification and exposure of the distal superior mesenteric vessels. The dissection is then carried proximally along the right lateral surface of the superior mesenteric vein, exposing it along its length. The ileocolic and right colic vessels are ligated. The dissection can be carried to the origin of the middle colic vessels for a tumour of the hepatic flexure. Finally, the mesenteric division is extended to the ileum and the transverse mesocolon, at the sites chosen for the division of the bowel. The ileocolic anastomosis may then be constructed end-to-end or side-to-side, either with hand sutures or with a stapling device (see Chapter 14).

Variations

Some surgeons prefer to ligate the vascular pedicle before mobilising the right colon, which is then mobilised in a retrograde direction.

If the tumour is at the hepatic flexure, lymphatic drainage alongside the right branch of the middle colic must be included in the resection (Figure 22.19) and the right half of the greater omentum should be removed with the specimen, with no attempt made to separate it from the colon (see Figure 22.22). If the tumour is in the caecum, a longer segment of terminal ileum should be sacrificed if the tumour appears to be draining along the terminal arcade of the superior mesenteric artery (see Figure 22.17).

A tumour that is adherent to the anterolateral abdominal wall should be excised with the adherent disc of peritoneum and abdominal wall muscle. Similarly, an adherent loop of small bowel should be excised with the specimen. Posterior invasion may necessitate sacrifice of the ureter or a disc of duodenum, but the surgeon must evaluate carefully whether this will remove all palpable tumour. If all the tumour cannot be removed, an ileocolic bypass will almost certainly be a wiser palliative procedure (Figure 22.20). A mobile tumour, however, is better resected than bypassed, even if there are inoperable secondaries in the para-aortic nodes or liver, as a tumour left *in situ* may continue to bleed and small bowel loops may become involved and obstruct.

LAPAROSCOPIC RIGHT HEMICOLECTOMY

A Lloyd–Davies position allows the surgeon or an assistant to stand between the legs of the patient. The leg supports also help to prevent the patient from slipping when steep Trendelenburg or reverse Trendelenburg positions are needed to help retract small bowel, but shoulder supports should be used as well. An umbilical camera port is used and three further ports established on the left side of the abdomen. A 12-mm port in the left iliac fossa, through which a stapler can be passed if necessary, and two 5-mm ports, one suprapubically and the other in the left upper quadrant for use by an assistant, form a satisfactory arrangement. The exact position of the ports will depend on the preference of the individual surgeon and the underlying pathology. The dissection is usually started medially with the ileocolic pedicle. The small

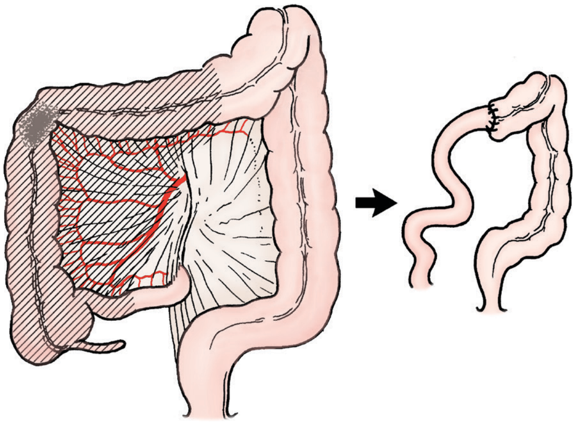

Figure 22.19 *A right hemicolectomy for a tumour at the hepatic flexure should include in the resection specimen the lymphatic channels alongside the right branch of the middle colic artery.*

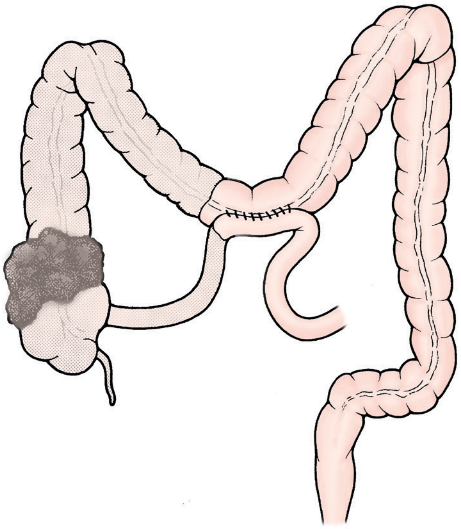

Figure 22.20 *An ileocolic bypass will relieve the obstruction from a right-sided colonic tumour, but resection of the primary tumour offers better palliation, even in the presence of metastatic disease.*

bowel is moved into the left side of the abdomen so that the mesentery of the caecum and ascending colon is uncovered. This mesentery is then grasped close to the caecum and retracted laterally and towards the anterior abdominal wall. The ileocolic pedicle is thus placed under tension and is visible as a tented fold in the mesentery.

Dissection starts by dividing the peritoneum immediately below the ileocolic vessel to enter the retroperitoneal plane behind the mesentery. This plane is then developed superiorly and laterally by precise blunt dissection. When followed correctly, this plane is bloodless, even without using any coagulation, and excessive bleeding usually indicates the wrong plane has been entered. The duodenum will be identified medially and is pushed gently posteriorly away from the mesentery. Once the dissection has passed behind the ileocolic pedicle, a window can be made through the mesentery to allow division of the pedicle with a vascular laparoscopic stapler. The right colic vessels are dealt with in a similar fashion. Clips are a cheaper alternative to a stapler, but require more dissection to skeletonise the vessel before they can be applied.

The retroperitoneal plane can then be followed superiorly over the curve of the duodenum and the pancreatic head and laterally behind the colon as far as the abdominal sidewall. The mobilisation of the colon is then completed by dividing the peritoneum laterally along the white line. Where a bulky caecal tumour distorts the anatomy around the ileocolic pedicle, a lateral to medial dissection may be carried out in the same fashion as for the open operation, but the view is often more limited.

As an incision is required to deliver the tumour, the final dissection of small bowel mesentery, omentum up to the resection margins on the bowel and finally the anastomosis itself may be carried out as an open procedure after delivery of the specimen. A small midline incision is made and the edges of this incision are protected by a plastic wound protector to reduce the risk of seeding tumour cells into the wound. If a bulky tumour or colon cannot be easily delivered, the wound should be enlarged to avoid the risk of perforating the tumour during aggressive attempts at delivery. Anastomosis is then carried out as for an open operation, and the abdomen closed.

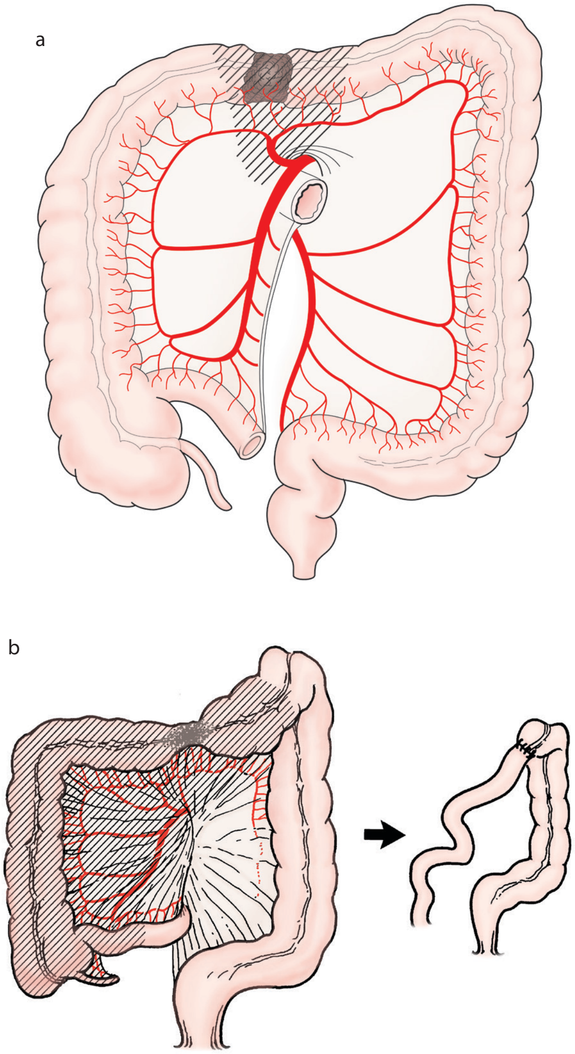

Figure 22.21 *In the resection of a transverse colon cancer the surgeon has two main options. (a) A transverse colectomy with a radical lymphadenectomy based on the middle colic artery is a good oncological resection. It is suitable for patients with a long transverse colon and a good marginal artery around the splenic flexure. (b) An extended right hemicolectomy, which is preferred by many surgeons. The resection specimen should still include the lymphatic channels alongside the middle colic artery.*

Transverse colectomy

There are often several alternative strategies for a cancer in the transverse colon. A radical lymphadenectomy is the fundamental consideration, and this is planned on the basis of the arterial supply. This will then dictate the segment of bowel that must be excised and the mobilisation necessary to bring the ends together for the anastomosis. A transverse colectomy is occasionally appropriate for a tumour near the apex of a long transverse colon. The vascular pedicle, with the associated lymphatic vessels, is the middle colic artery, and minimal dissection is required (Figure 22.21a). The drawback is a colocolic anastomosis using the area proximal to the splenic flexure, where blood supply may be marginal. Many surgeons therefore prefer to perform an extended right hemicolectomy for tumours of the transverse colon, and the well-vascularised terminal ileum is then used for a safer ileocolic anastomosis (Figure 22.21b). A more major dissection is offset by a more reliable anastomosis. In either operation the middle colic pedicle is ligated at its origin, and the greater omentum removed with the specimen after separation of the greater omentum from the stomach by multiple ligations of gastroepiploic vessels (Figure 22.22).

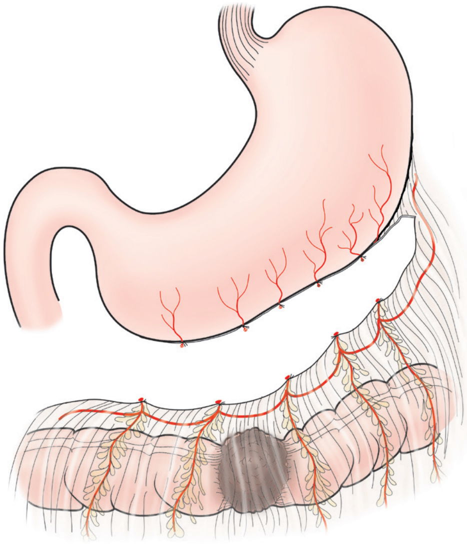

Figure 22.22 *The omentum should be excised* en bloc *with a tumour of the transverse colon. No attempt is made to separate the omentum from the colon; instead, it is freed from the greater curve of the stomach by multiple ligations of gastroepiploic vessels.*

Extended right hemicolectomy

An extended right hemicolectomy is an alternative resection to a transverse colectomy for a transverse colon cancer; the colonic resection can be further extended to make it an alternative to a left hemicolectomy for a cancer of the splenic flexure or descending colon.

If an extended right hemicolectomy is performed for a growth in the transverse colon, it must be remembered that the lymphatic drainage of the tumour will be alongside the middle colic artery, and it is this vessel that should be divided near its origin. Similarly, when an extended right hemicolectomy is performed for tumours at, or below, the splenic flexure, the lymphatic drainage alongside the ascending left colic artery is the most important, and this is the vessel that should be divided at its origin to secure a radical lymphadenectomy (see Figure 22.2). The level at which the right colic vessels are divided is not important.

Laparoscopic dissection is the same, in principle, as for an open extended right hemicolectomy. The right colonic mobilisation is carried out with a medial to lateral dissection. Good retraction of the transverse colon can be difficult laparoscopically, resulting in a lengthy, difficult dissection. It is often easier to carry out the bulk of the dissection laparoscopically, but to take the middle colic vessels via the same short midline incision used to retrieve the specimen.

Left hemicolectomy

This is the standard operation for colonic tumours in the colon supplied by the inferior mesenteric artery (Figure 22.23). An anterior resection of the rectum is an extension of the basic left hemicolectomy. The inferior

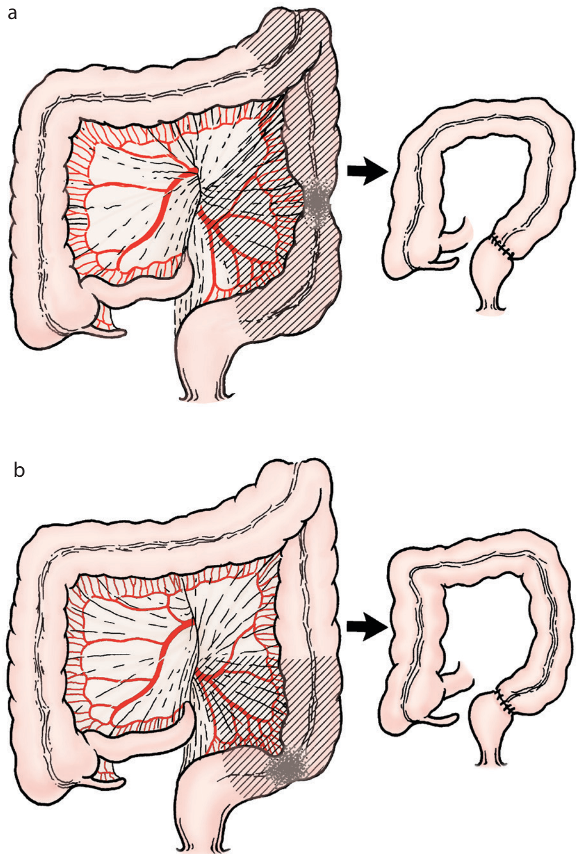

Figure 22.23 *A left hemicolectomy is based on the lymphatic drainage around the inferior mesenteric artery. (a) The whole left colon with the exception of the rectum has been excised. (b) Even after a high ligation of the inferior mesenteric artery, a good marginal artery may be sufficient to allow retention of the whole descending and proximal sigmoid colon.*

mesenteric artery is ligated close to its origin from the aorta and the lymphadenectomy thus extends to the mesenteric root. The extent of the colonic excision is shown in Figure 22.23a. The rectum below the peritoneal reflection has an adequate blood supply from below. The marginal artery allows preservation of the descending colon and, variably, of the sigmoid. It may, therefore, be possible with distal tumours to excise only the sigmoid colon (Figure 22.23b). In all situations, however, great care must be taken to perform a radical excision of the lymph nodes and lymphatic channels in the line of drainage of the tumour. Incisions or tears into the 'mesentery' are into potentially malignant channels, and thus jeopardise cure. There is a choice of an open or laparoscopic approach for a left hemicolectomy.

OPEN LEFT HEMICOLECTOMY

A Lloyd–Davies position (see Figure 13.1, p. 210) is advantageous as this allows the surgeon to stand between the legs for optimal access when releasing the splenic flexure. In addition, retraction from this position is useful if pelvic dissection is required. Also, if the anastomosis has to be lower than anticipated, and access is difficult for a hand-sewn anastomosis, a circular mechanical stapler can be inserted *per anum*.

A midline incision allows better access for splenic flexure mobilisation and high ligation of the inferior mesenteric artery than the alternative oblique left iliac fossa incision. The principles of mobilisation of the left colon are similar to those of the right colon. Before the lateral peritoneum is divided it may be necessary to divide adhesions between the sigmoid colon and the anterolateral abdominal wall or pelvic organs. These peritoneal adhesions may be congenital, but more often they are inflammatory or postoperative adhesions, for example following previous gynaecological surgery. If, however, the tumour is in the sigmoid colon, and these adhesions are dense, they may represent local malignant infiltration. The resection must therefore be more radical in order to prevent rupturing the tumour. An ovary, a disc of abdominal wall muscle or a dome of the bladder may have to be excised *en bloc* with the tumour. A sigmoid tumour may be folded down into the pelvis with malignant adhesions to the anterior rectal wall. In this situation an anterior resection will be necessary for a tumour that was as high as 30 or 40 cm at endoscopy.

Left colon mobilisation is then continued by incision of the peritoneum lateral to the distal descending colon (Figure 22.24) and the plane entered behind the retroperitoneal 'mesentery'. Lateral mobilisation of the descending colon is continued up towards, and finally round, the splenic flexure. It is easy at this stage to damage the spleen. Damage is most commonly caused through tearing an omental adhesion off the lower pole of the spleen by excessive retraction on the colon or, more frequently, on the omentum. Good access is essential for a difficult mobilisation of a high splenic flexure, and any reluctance to extend the wound should be overcome. A high splenic flexure is best approached from both sides. The plane between transverse colon and greater omentum is opened and followed laterally towards the flexure. This manoeuvre allows the omentum to be retracted anteriorly, releasing any tension on adhesions between the omentum and the spleen, and guides the dissection into the correct plane. With gentle traction on the colon, the peritoneum is divided around the flexure. If visualisation is still poor, a finger inserted under the peritoneum to draw down and protect the colon is also helpful in displaying the final strands to be divided (Figure 22.24). A splenic flexure tumour will require the left side of the omentum to be excised *en bloc* with the specimen. The greater omentum is then not separated from the colon, but instead is separated from the stomach by division of the gastroepiploic vessels, as shown in Figure 22.22. The spleen may have to be excised with the specimen in a locally advanced splenic flexure tumour. In addition, it can be damaged inadvertently during splenic flexure mobilisation. A damaged spleen can sometimes be saved, but unfortunately a splenectomy is often required (see Chapters 15 and 20). Once the splenic flexure has been fully released, it can be lifted forwards and medially and its 'mesentery' released from the underlying pancreas and duodenojejunal flexure.

Mobilisation of the descending and sigmoid colon is continued medially by following the areolar plane between mesenteric structures anteriorly and gonadal vessels and ureter posteriorly. A damaged gonadal vessel can be sacrificed, but the ureter should be identified early in this dissection and carefully preserved (Figure 22.25a). The ureter is occasionally involved in a tumour and has to be sacrificed (see Chapter 26). If preoperative imaging suggests that the tumour may be close to locally advanced disease, then elective stenting of the ureter at the start of the operation may be helpful. When the dissection has reached the midline, it is helpful to insert a swab into the extremity of the dissection before turning the colon back to the left, and making a peritoneal incision, posteriorly on the right of the sigmoid mesentery (Figure 22.25b). The swab is visible immediately on dividing the peritoneum and aids identification of the window behind the inferior mesenteric artery, but in front of the hypogastric nerve plexus on the surface of the aorta. This plane is then followed up until the origin of the inferior mesenteric artery can be felt between finger and thumb. The artery and the vein are clamped, ligated and divided separately; many surgeons prefer a transfixion ligation for the artery. Care should be taken to preserve the sympathetic nerve fibres on the anterior surface of the aorta, and for this reason ligation of the inferior mesenteric artery 1–2 cm from its origin is preferable to a

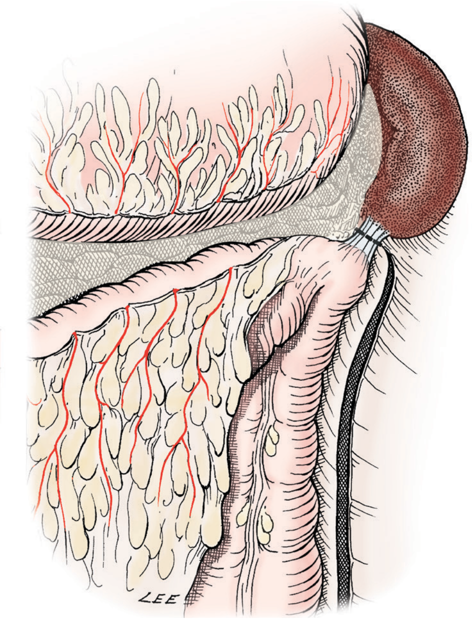

Figure 22.24 *Left colon mobilisation commences with an incision of the peritoneum lateral to the distal descending colon. Above the transverse colon the greater omentum has been separated from the stomach by division of epiploic vessels. (Except for splenic flexure tumours, the alternative plane between the transverse colon and the omentum is preferable.) A finger introduced along the distal transverse colon and round the flexure, deep to the remaining peritoneum that is tethering it, will define the remaining tissue to be divided and protect the colon from injury. Excessive traction on the colon may tear adhesions off the spleen and damage it.*

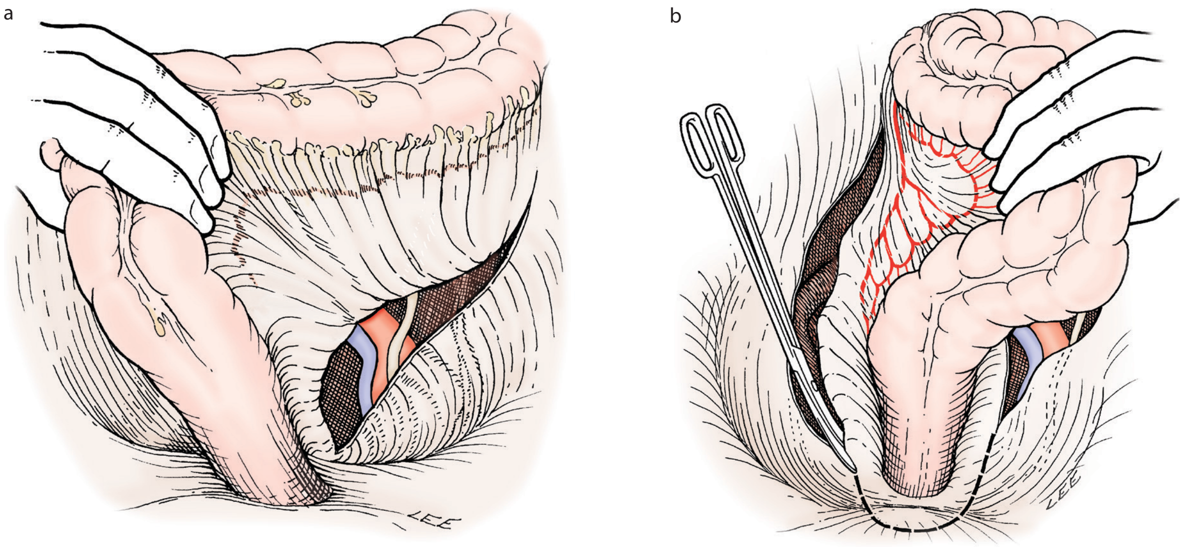

Figure 22.25 *A left hemicolectomy. (a) The descending and sigmoid colon mobilisation starts on the left, and the ureter must be identified early. (b) When the dissection from the left has reached the midline, the colon is swung to the left. The right leaf of the peritoneum is incised to form a window in front of the aorta and behind the mesenteric package, which contains the inferior mesenteric artery, its branches and the lymphatic drainage of the hind gut. The inferior mesenteric artery is then ligated and divided close to its origin. The anterior and lateral peritoneal incisions around the rectum allow it to be drawn up to make an anastomosis easier.*

flush tie on the aorta. As the artery is skeletonised prior to clamping, the fat and lymphatic tissue of the proximal centimetre of mesentery can be drawn into the specimen.

At this stage, a 'division of convenience' of the colon improves access for the final dissection. Division with a mechanical stapler or between small crushing clamps is suitable. It is important not to divide the colon too proximally, remembering that excessive length can be trimmed but colon that will not reach the rectum may pose a major challenge to a restorative anastomosis. The mesentery is then divided between the inferior mesenteric root and the colonic division. The sigmoid colon can now be retracted anteriorly to display the continuation of the posterior areolar plane over the pelvic brim and into the pelvis behind the mesorectum. The autonomic nerves lying on the aorta and the posterior pelvic brim should be carefully preserved. Only minimal dissection is required in the pelvis, and is employed simply to gain rectal mobility for the anastomosis. Division of the peritoneum, lateral and anterior to the rectum, will also allow further upward mobilisation of the rectum (Figure 22.25b). The level of the distal resection site is finalised. This should be below the pelvic brim and not more than a few centimetres above the peritoneal reflection. A higher division carries a risk of inadequate perfusion of the distal end of the anastomosis. The mesentery behind is divided between forceps and ligated. A right-angled clamp is placed across the bowel to prevent contamination from above, and the bowel is divided. The rectum is emptied by suction and liberally washed with a tumouricidal solution.

Attention is now turned to the proximal end, and its viability is checked. If there is any doubt, it must be resected back to well-vascularised bowel. It should reach without tension to the anastomotic site and, if difficulty is encountered, a second higher division of the inferior mesenteric vein below the body of the pancreas, as routinely performed in an anterior resection, provides extra length. The anastomosis may be performed using either a hand-sewn technique or a circular stapling device (see Chapter 14). The surgeon will find a difficult hand-sewn anastomosis easier if the first suture is placed on the posterior wall furthest away, taking the initial bite from the rectal side of the anastomosis. If this suture is accurately placed, then each subsequent suture, when working along the back wall, becomes easier. The anterior wall poses no difficulty unless mobilisation has been inadequate and there is unacceptable tension. No drain is recommended unless there has been more extensive pelvic dissection.

Variations

A radical lymphadenectomy, with ligation of the inferior mesenteric artery close to its origin, will often still allow preservation of the entire descending and sigmoid colon on the marginal artery. It is sometimes therefore possible in a distal sigmoid tumour to perform a radical resection and still have sufficient length to anastomose without the need to mobilise the splenic flexure (see Figure 22.23b).

A locally advanced left colonic neoplasm may be unresectable. Obstruction can be relieved by an intraluminal stent or a proximal loop colostomy. A splenic flexure tumour can sometimes be bypassed (Figure 22.26).

LAPAROSCOPIC LEFT HEMICOLECTOMY

The patient is placed in the Lloyd–Davies position with shoulder supports to prevent patient slippage on the table.

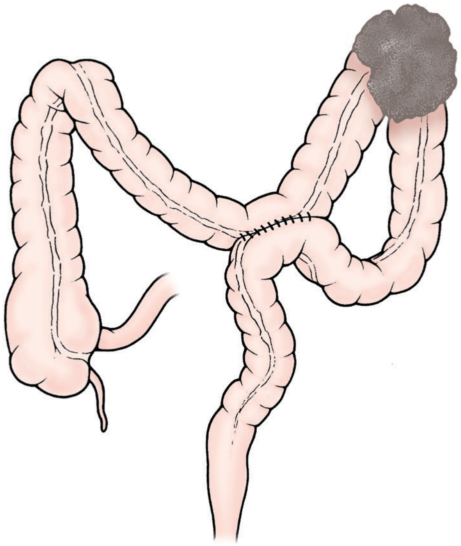

Figure 22.26 *An irresectable splenic flexure tumour with invasion of spleen, pancreas and kidney can be bypassed with a side-to-side anastomosis between the transverse and sigmoid colon.*

Port sites will depend on the preference of individual surgeons, but one satisfactory arrangement is an umbilical camera port, a 12-mm main working port placed just above the right anterior superior iliac spine and an additional 5-mm port in each flank.

A medial to lateral approach is commonly used to mobilise the left colon as, with a lateral approach such as that used in open surgery, the fully mobilised sigmoid colon can obscure the operative field. The patient is positioned steeply head down, and the omentum, transverse colon and small bowel moved as much as possible into the right upper quadrant to expose the mesentery of the sigmoid colon. This mesentery is grasped near the distal sigmoid colon and retracted laterally and towards the anterior abdominal wall by an assistant. This places the inferior mesenteric artery under tension and makes its course visible through tenting the overlying mesentery. The retroperitoneal plane is then entered by an incision in the peritoneum, which starts to the right of the inferior mesenteric artery at the pelvic brim and continues to the origin of the inferior mesenteric artery. Blunt dissection opens up this plane behind the mesentery, which is then developed laterally in a similar fashion to the dissection in a laparoscopic right hemicolectomy.

The ureter is encountered early in this plane and should be pushed posteriorly to prevent it being lifted with the mesentery. This dissection should be developed laterally behind the colon as far as the colonic peritoneal attachment to the abdominal sidewall, and continued up towards the splenic flexure. Once the dissection has passed behind the inferior mesenteric artery, a window is made through the mesentery on the lateral side, and the vessel is divided with a vascular laparoscopic stapler or clipped and divided.

The remainder of the mobilisation of the left colon now proceeds with the division of any adhesions from the sigmoid colon to the abdominal side wall, followed by lateral division of the peritoneum continuing upwards towards the splenic flexure. As the splenic flexure is approached, the head-down tilt can be reduced to bring the bowel closer to the surgeon. If mobilisation of the splenic flexure is required, this is done with the patient in a reverse Trendelenburg position. The plane between transverse colon and omentum is entered and dissection proceeds distally as in an open operation.

Once the colon is sufficiently mobilised, the distal resection is carried out. This is usually at the level of the upper rectum to allow a stapled anastomosis to be created with a circular stapling device. The mesorectum is divided with the Harmonic™ scalpel or an alternative energy source and the bowel with a linear stapler. Mobilised colon and tumour are then delivered through an incision, which may be periumbilical, in the left iliac fossa, or a Pfannenstiel incision as per the surgeon's preference. The wound edges must be protected.

The proximal bowel is divided, with care being taken to ensure there is adequate length for it to reach for an anastomosis without tension. The anvil of the circular stapling device is then secured within the divided proximal bowel with a purse-string suture and returned to the peritoneal cavity. The incision is closed, the pneumoperitoneum re-established and the circular stapling device introduced *per anum*. The delivery of the spike through the stapled rectal stump, the locking of the anvil onto it and the approximation of the two portions of the stapler are all completed under visualisation via the laparoscope.

RADICAL RECTAL RESECTIONS

Historical perspective

A radical resection for a carcinoma of the rectum requires excision of the primary tumour in continuity with its lymphatic drainage. The earliest attempts at excision were performed from the perineum or through a *posterior* approach[11] (see Chapter 24). These approaches do not offer sufficient access for a radical lymphadenectomy.

Abdominoperineal excision of the rectum later became the standard radical excision for rectal cancer, with the opportunity to include a radical lymphadenectomy. However, an increasing understanding of the mode of spread and lymphatic drainage of rectal cancers has resulted in the conclusion that a purely abdominal procedure, or *anterior resection* of the rectum, is oncologically sound for the vast majority of cases with the exception of the very lowest or most advanced rectal cancers. There is no significant submucosal spread of rectal or colonic tumours, and it is therefore safe to resect a rectal cancer with a distal bowel wall margin of around 1 cm. The lymphatic drainage of the rectum is almost exclusively in a proximal direction along the inferior mesenteric artery. Lymphatic drainage in association with the inferior or middle rectal arteries in low rectal cancer continues to be an area where the Japanese experience differs from that in the West.[12] In the UK it is generally believed that it only occurs late in the disease process and is associated with advanced and incurable tumours. However, the initial lymphatic drainage of the tumour fans out into the mesorectum, and at least 5 cm of mesorectum distal to the tumour must be excised (Figure 22.27). Therefore, any tumour within 10–12 cm of the anal verge requires a total mesorectal excision (TME). If mesorectum involved in the tumour is breached during dissection, local recurrence is common. Originally, local recurrence was thought to be related both to residual tumour in the distal bowel wall remnant as a result of submucosal spread and also to lymphatic drainage along both surfaces of the levator ani muscles and out into the ischiorectal fossae (Figure 22.28). It is now known that neither route of spread is a significant issue. These, however, were the oncological justifications for the abdominoperineal resection. In addition, before the advent of mechanical staplers the technical difficulty in hand-sewn anastomoses deep in the pelvis usually discouraged anal preservation. An abdominoperineal approach can, at least in theory, be avoided in all rectal cancers except those that extend to the dentate line or invade the anal sphincters.[13] Excision of very low rectal cancers is technically difficult, and as better results are achieved by surgeons with a special interest, referral should be considered. The preoperative assessment of these tumours is extremely important for the planning of surgery and of any adjuvant therapy, and this is discussed further in Chapter 23. In addition to pelvic MRI scanning, a preoperative digital assessment and endoanal ultrasound examination, either in the awake patient or under anaesthesia, can form an important part of the assessment of very low tumours.

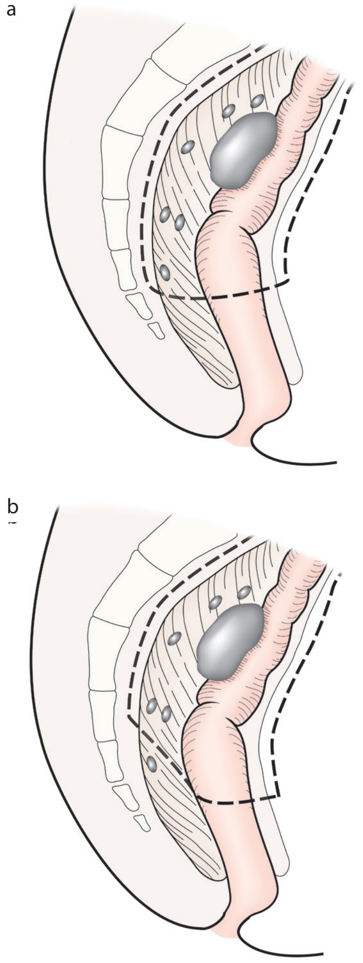

Figure 22.27 *The initial spread from a rectal tumour into the mesorectum is fan-shaped. Nodes up to a distance of 5 cm distal to the primary tumour may contain metastases. (a) A high anterior resection with mesorectal transection can only be oncologically sound if 5 cm of mesorectum distal to the primary tumour is removed. (b) An unsatisfactory cancer operation. The rectum has been divided at the same height, but the 'coning-in' through the mesorectum has cut across involved lymph nodes.*

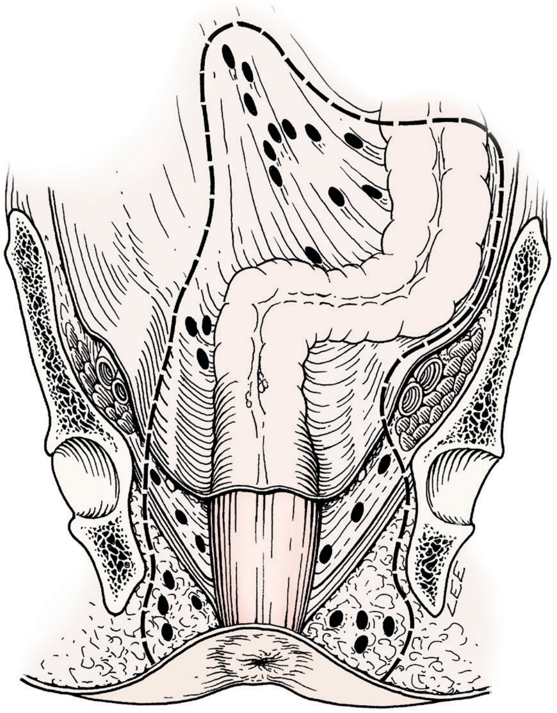

Figure 22.28 *The original hypothesis of the lymphatic drainage of the rectum, as described by Ernest Miles, which formed the oncological basis for the abdominoperineal excision of the rectum for cancer. It is now known that no lymphatic drainage occurs through the levator muscles into the ischiorectal fat from tumours above the dentate line.*

Anterior resection

The principles of an anterior resection are similar for open and laparoscopic surgery and so will be described together. Laparoscopic surgery often gives a better view in a narrow pelvis, but obtaining good retraction can be more difficult. If there is concern during surgery as to whether a good oncological resection can be completed laparoscopically, then conversion to an open operation is mandatory.

The patient is placed in the Lloyd–Davies position and the operation commences with a digital rectal examination (and vaginal examination in women) to assess the tumour. The abdomen and perineum are prepared for surgical access. Postoperatively, there are advantages with suprapubic rather than urethral catheterisation, in particular for men who may have a degree of prostatic outflow obstruction. The technique and its advantages are discussed in Chapter 26. The initial mobilisation and dissection for an anterior resection are identical to that for a left hemicolectomy, unless there is a minor modification to avoid mobilisation of the splenic flexure. This modification is dependent on the sigmoid colon proving suitable for reconstruction. If there is any diverticular thickening, a sigmoid neorectum is rendered unsuitable due to reduced distensibility. In addition, the sigmoid colon may have a precarious blood supply after division of the inferior mesenteric artery. Vascularity of the sigmoid colon may be improved by retention of the ascending left colic artery, which arises as a branch of the inferior mesenteric artery within 2–3 cm of its origin (see Figure 22.2). Radicality of the lymphadenectomy is probably not significantly reduced if, on skeletonisation of the artery prior to dividing, all the fat and lymphatic tissue is drawn into the specimen.

In most situations, however, the surgeon will have decided to mobilise the splenic flexure, and this is often most satisfactorily performed before the pelvic dissection. A single division of the inferior mesenteric vein, at the level of the division of the artery, still leaves the vein as a cord at the base of the mesentery, preventing the descending colon from reaching to the pelvic floor. A second higher ligation of the inferior mesenteric vein at the lower border of the pancreas affords excellent extra mobility of the left colon (see Figure 22.3). The transverse mesocolon is retracted upwards and the inferior mesenteric vein is then usually readily identified. The flimsy peritoneum is dissected on the left side of the duodenojejunal flexure to enter a bloodless plane, either side of the inferior mesenteric vein. The vein is then either divided between artery forceps and ligated, or clipped. Care must be taken over this step as an unsecured vein may retract underneath the pancreas and cause troublesome bleeding. For example, it is important to ensure that a proximal ligature is tied securely, with an adequate venous remnant beyond the ligature. After this high division of the vein, the surgeon will encounter a large mesenteric window of peritoneum, extending between the ligated distal vein and the marginal artery. This can be divided, carefully preserving the marginal vessels, to allow the left colon to be drawn down into the pelvis. This manoeuvre leaves an isolated segment of the inferior mesenteric vein in the mesentery.

POSTERIOR PELVIC DISSECTION

After full mobilisation of the left colon, dissection of the posterolateral plane is then continued down into the pelvis. The rectum and mesorectum are lifted forwards and upwards, out of the concavity of the sacrum. In the open operation this retraction is with a St Mark's retractor, while retraction can be achieved laparoscopically with a combination of Johan grasping forceps. One is placed on the distal sigmoid mesocolon and is held by the assistant; the second is held in the left hand of the surgeon. It is this retraction that displays the plane for dissection. The mesorectum should appear as a smooth bilobar structure with a glistening surface suggestive of a 'capsule', and similar to that of a lipoma. The plane is between this and the thin fascia covering the structures of the pelvic sidewall, and is crossed by fine strands of areolar tissue. The autonomic nerve plexi are located deep to the pelvic sidewall fascia. If the areolar plane is opened by blunt dissection, it does not separate accurately and both the autonomic nerves and the mesorectum may tear. The incidence of postoperative urinary and sexual dysfunction will be increased and there is a greater risk of local tumour recurrence. Sharp dissection is either by scissors, diathermy or Harmonic™ scalpel. Diathermy or Harmonic dissection is more haemostatic than scissors, but more dangerous if the surgeon strays from the correct plane. Thermal damage to anatomically intact autonomic nerves is an additional concern. The 'wishbone' of the sympathetic hypogastric nerves will be visible at the pelvic brim posteriorly, and these nerves are easily injured if the dissection strays too far posteriorly (Figure 22.29). If the correct plane, on the front of the aorta between the back of the pelvic mesocolon and the superior hypogastric plexus, has been identified, this will lead the dissection into the pelvis in the correct plane medial to the hypogastric nerves. There is a second areolar plane outside the nerves, but this should only be followed for a tumour that is threatening circumferential excision margins at this site. This outer plane sacrifices autonomic nerves, and troublesome bleeding may

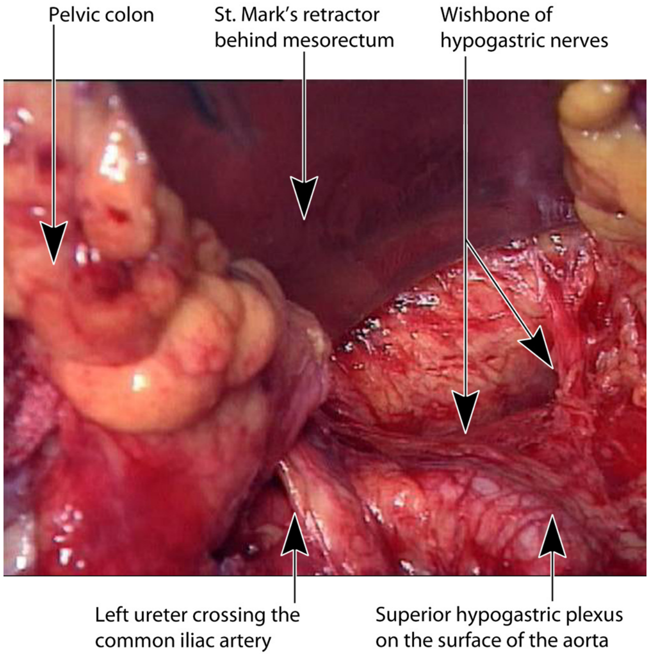
Pelvic colon
St. Mark's retractor behind mesorectum
Wishbone of hypogastric nerves
Left ureter crossing the common iliac artery
Superior hypogastric plexus on the surface of the aorta

Figure 22.29 *View looking down into the pelvis during mobilisation of the mesorectum. (Photograph by kind permission of Tom Cecil, Basingstoke)*

occur from pre-sacral veins. The final posterior dissection is in a forward direction, beneath the lobes of the mesorectum, along the surface of the levator muscles, but is completed only when mobility has been increased by the lateral and anterior dissection.

LATERAL PELVIC DISSECTION

The lateral plane on the surface of the mesorectum is best approached from the plane already developed posteriorly. It may be difficult to identify from above and, therefore, early lateral division of the peritoneum may merely lead the surgeon into the wrong plane. The hypogastric nerves are easily damaged at this stage, but the correct plane of dissection on the lateral surface of the mesorectum will allow the hypogastric nerves, and then the inferior hypogastric plexi, to fall back safely onto the pelvic sidewall. The small rectal branches from the plexi cross the plane of dissection and are divided. The original descriptions of lateral ligaments, which were clamped and ligated, were probably the hypogastric plexi tented away from the pelvic sidewall by medial traction on the specimen. The middle rectal artery, if present, will also cross the areolar plane and requires diathermy coagulation or, occasionally, ligation. Earlier descriptions of large middle rectal vessels were almost certainly vessels of the mesorectum encountered when dissection was too medial and through, rather than around, the mesorectum. 'The pillar' of the erigent nerve, which is the parasympathetic outflow from S3 to the inferior hypogastric plexus, can be identified beneath the fascia of the pelvic sidewall (Figure 22.30). It is at risk of injury if the deep dissection strays too lateral. It is now known that the circumferential margin is important in preventing local recurrence in rectal cancer.[14] However, dissection in the correct plane will normally ensure adequate margins, except in advanced tumours that have transgressed the confines of the mesorectum. In these circumstances, the surgeon may be forced to sacrifice pelvic autonomic nerves to achieve adequate oncological clearance.

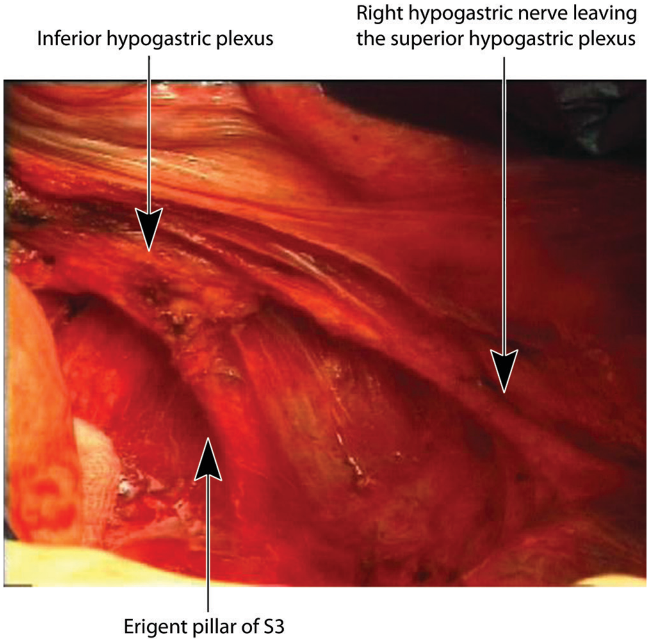
Inferior hypogastric plexus
Right hypogastric nerve leaving the superior hypogastric plexus
Erigent pillar of S3

Figure 22.30 *The right lateral pelvic sidewall after full rectal mobilisation. (Photograph by kind permission of Tom Cecil, Basingstoke)*

ANTERIOR PELVIC DISSECTION

Male patients

The anterior plane in the male pelvis lies between the thin anterior mesorectal tissue and the prostate and seminal vesicles. It is entered by incising the peritoneum just anterior to the rectovesical pouch and entering an areolar plane, which leads to the upper pole of the seminal vesicle. Alternatively, the lateral dissection, when carried forwards on the surface of the mesorectum, will lead round to the vesicles. An anterior tumour that has invaded the peritoneum and folded over with a malignant adhesion is easily disrupted at this point. The anterior pelvic peritoneal incision shown in Figure 22.25b should be made more anteriorly in this situation. A forceps or laparoscopic grasper can then be applied to the divided peritoneum to hold it up and hold this vulnerable area closed and prevent rupture. This should help prevent traction disruption of the tumour during the deeper pelvic dissection. The dissection is kept on the posterior surface of the seminal vesicles. Denonvillier's fascia comes into view as a shiny white layer on the anterior surface of the distal anterior mesorectum. Dissection is continued down in front of Denonvillier's fascia. This thin fascial rectogenital septum forms a temporary barrier to anterior tumour invasion. Distally, Denonvillier's fascia curls forwards to fuse with the base of the prostate and must, therefore, be divided at some stage during the rectal excision and the plane directly on the anterior mesorectum re-entered. The final anterior dissection in front of Denonvillier's fascia puts the neurovascular bundles and the prostatic plexus at risk of injury. It is therefore safer to cut Denonvillier's fascia at a higher level and to continue any final dissection behind it. In very low anterior tumours, however, the risk of nerve damage must be balanced against involved tumour margins, and the dissection should proceed more distally before dividing Denonvillier's fascia.

Female patients

The anterior plane in the female pelvis lies between the thin anterior mesorectum and the posterior vaginal wall. Avoidance of nerve damage is also important, but until recently has been largely ignored. Denonvillier's fascia is a less well-developed structure and an anterior tumour can breach the thin layer of anterior mesorectum relatively early. A cuff of posterior vagina should be included with the specimen if there is vaginal invasion or any concern over circumferential tumour margins at this point.

Locally advanced tumours

These tumours may require a more radical excision, including the sacrifice of autonomic nerves with the removal of internal iliac nodes, an *en-bloc* hysterectomy and excision of a seminal vesicle or a portion of involved prostate or bladder. A full anterior pelvic clearance with urinary diversion is occasionally justified (see also Chapters 26 and 27). These locally advanced tumours require careful preoperative assessment and multidisciplinary management with a combination of surgery, radiotherapy and chemotherapy for optimal results (see also Chapter 23).

FINAL PELVIC DISSECTION

The final dissection is important in very low tumours. A posterior condensation of fascia between the coccyx and the anorectum is released to display a bare rectal muscle tube below the mesorectum, which passes through the puborectalis portion of the levator ani. Anteriorly, the dissection passes through Denonvillier's fascia onto the distal extremity of the thin anterior mesorectum and finally, below this, onto the bare rectal muscle tube. The anatomical plane between the visceral and somatic structures continues into the intersphincteric plane. A tumour at the anorectal junction, which is still a T2 lesion, can thus sometimes be adequately excised by following this plane. A T3 tumour, however, in this position has no mesorectum around it and will immediately breach the plane and invade the external sphincters (Figure 22.31). An abdominoperineal resection then becomes essential for oncological clearance.

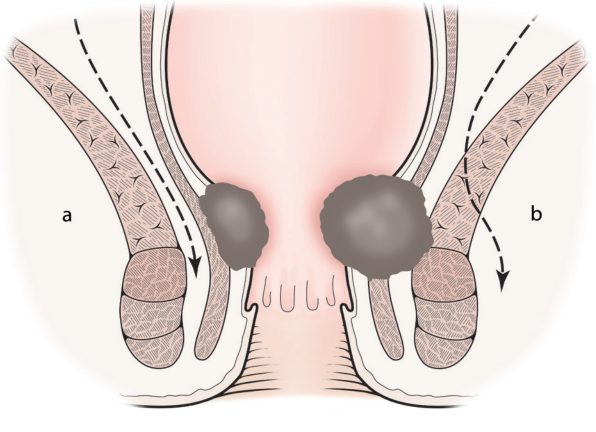

Figure 22.31 *A lower-third rectal cancer. (a) A T1 or T2 tumour, which has not breached the plane between the visceral and somatic tissue, can still be satisfactorily excised without sacrifice of the external sphincter. (b) A T3 tumour will breach this plane as there is no mesorectum surrounding the bowel at this level. An oncologically satisfactory excision is no longer possible without sacrifice of the external sphincters. The plane for an anterior resection must be abandoned before the tumour is breached, and the plane for excision is through the levator ani muscles.*

After completion of the dissection, the rectum should be sealed below the tumour to prevent further contamination from intraluminal malignant cells. At open surgery the simplest technique is with a TA™ 30 or 45 (30 or 45 mm length) or with a similar linear stapler (see Chapter 14). This is a safer method of occlusion than with a right-angled clamp, which may slip and is difficult to position in a narrow pelvis. This staple line seals the distal end of the specimen to be removed. It must be below the tumour, but a margin of only a few millimetres does not compromise cure. The tumour is normally palpable through the rectal wall, but if there is any concern, an examination from below after the stapler is locked (but still not fired) can confirm the position. In a mid-rectal tumour, although a TME has been performed, the mesorectum is drawn up as the stapler is closed and a short cuff of distal rectum is left *in situ*. In a cancer of the distal rectum the stapler may have to be closed beyond the distal margin of the mesorectum in order to clear the tumour. The height of the anastomosis may therefore vary by 1–2 cm, even after a TME.

A proctoscope is inserted and the rectum washed with tumouricidal solution until the washings are clear of faecal residue. The TA™ 30 is then reloaded and placed distal to the first staple line and fired across the washed rectal stump. In very low tumours, this manoeuvre is easier if the TA™ 30 is left *in situ* after firing, to be used as a rectal retractor, and a new stapler used for the second staple line. The bowel is divided between the two lines of staples.

The staplers used in laparoscopic surgery divide as well as staple, so cannot be used to occlude the bowel prior to the tumouricidal washout. This can be done instead by application of a long-bladed Johan grasping forceps across the bowel as a clamp immediately distal to the tumour. Division of the bowel is performed with a stapler with an angled head, introduced through the 12-mm port near the right anterior superior iliac spine. The tumour and mobilised bowel can then be retrieved through a short transverse suprapubic incision with protected wound edges.

RECONSTRUCTION

The proximal bowel end is now reassessed for reconstruction. It must reach with ease into the depths of the pelvis, and further mobilisation may be required, especially if the original division of colon has had to be revised to a higher level to ensure a well-perfused bowel end. Further length can be obtained by dissection along the inferior border of the pancreas, releasing the left lateral attachment of the transverse mesocolon as far as the origin of the middle colic artery. There is frequently a small branch between the colonic mesentery and the inferior pole of the pancreas. This can be ligated and divided. Care must be taken with this manoeuvre, as simple diathermy will often lead to troublesome bleeding from the pancreas. Where there is still inadequate length, the left branch of the middle colic artery is often smaller than the more centrally placed branch and it can be divided near its origin. Once again, a window can be created extending to the marginal artery, and this can produce excellent length. If, on completion of this mobilisation, it is still clear that there is insufficient length, three options are available to the surgeon:

- The first is simply to transilluminate the mesentery and assess whether there are suitable points where vessels can be ligated.
- The second, which can often produce considerable improvement in mobility, is to mobilise the whole of the right colon. This is undertaken from the lower pole of the caecum around the hepatic flexure, such that the middle colic artery can be rotated downwards. The appendix and caecum will then frequently lie in the right upper quadrant and considerable additional length can be achieved.
- If, following these two manoeuvres, there is still inadequate length or the bowel does not appear to have sufficient vascularity for a safe anastomosis, then the preferred option is to divide the origin of the middle colic artery. The mobilisd caecum is moved downwards like a clock pendulum, such that the lower pole of the caecum sweeps in an arc towards the left iliac fossa and then up into the left upper quadrant. This leaves a long, well-vascularised segment of bowel in the region of the hepatic flexure available for a tension-free coloanal anastomosis.

After a total mesorectal excision and a low anterior resection, bowel function and continence were found to be better if a short colon pouch was created rather than forming a straight end-to-end coloanal anastomosis.[15] A short colon pouch (5 × 5 cm) is created with a GIA™ 60 linear stapling device. An enterotomy is made on the antimesenteric border about 6 cm from the closed end. The blades of the stapler are introduced, and a finger is swept between the blades to carry the mesentery out of the staple line before the device is closed. The instrument is then fired to anastomose the two limbs into a pouch (Figure 22.32a). The head of the circular stapling device is introduced into the pouch through the enterotomy made for the introduction of the linear stapler (Figure 22.32b). A purse-string suture is inserted at the edge of the enterotomy and

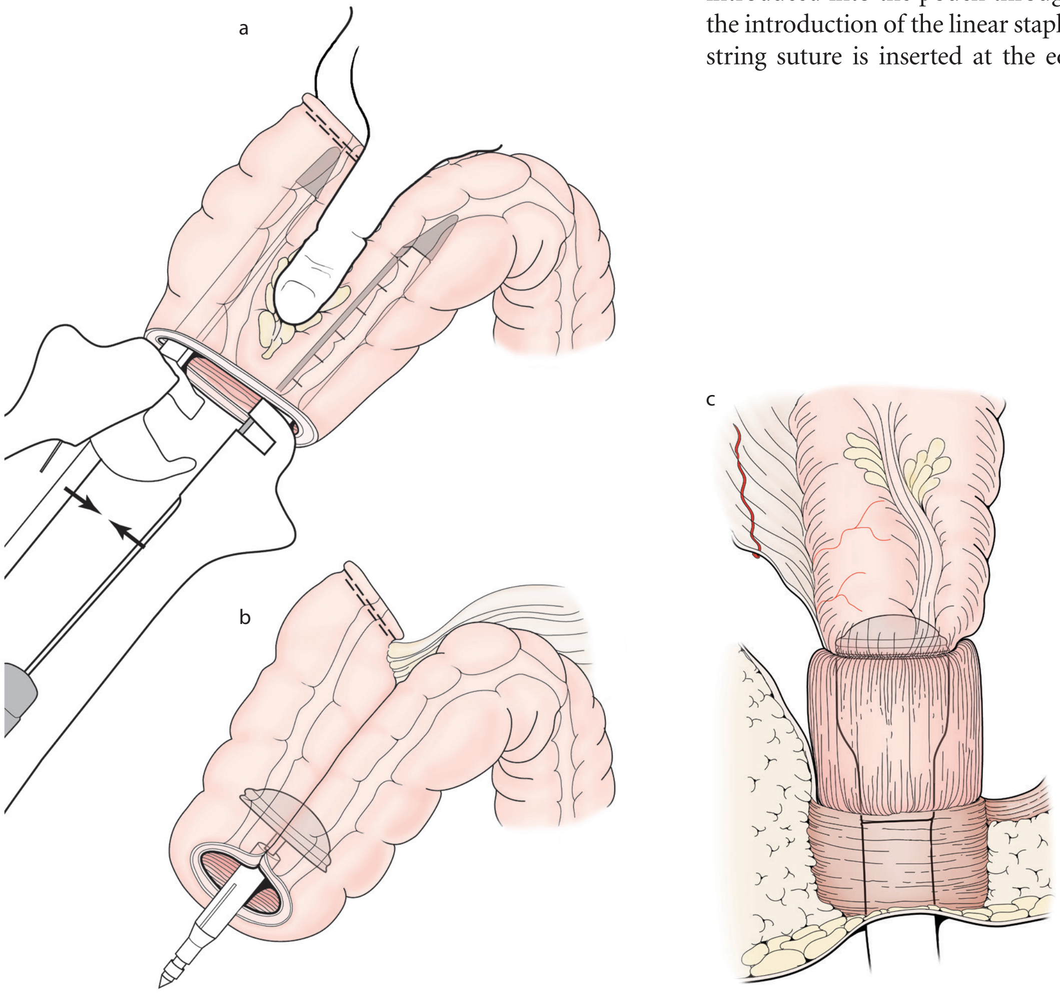

Figure 22.32 *A colon pouch is created with a linear stapling device introduced through an enterotomy about 6 cm from the closed bowel end. (a) The thick colonic mesentery must be swept out of the staple line with a finger before the device is closed and fired. (b) The head of the circular stapling device is then introduced into the colon pouch through the same enterotomy. (c) The anvil of the circular stapling gun is introduced through the anus, the two portions of the device are locked together and the bowel ends approximated.*

tightened to draw the bowel over the staples. In a laparoscopic anterior resection these steps can most easily be performed outside the abdomen after delivery of the specimen. The general principles of circular stapling techniques are described in Chapter 14. The main portion of the circular stapler is inserted through the anus. Care must be taken to cause minimal stretching of the anal sphincters, and gentleness and good lubrication are essential. The spike of the locking device is advanced through the anorectal stump, adjacent to the stapled closure. The bowel ends must then be orientated to exclude a twist before locking the two portions of the circular stapling device together. It is very easy to inadvertently include the vagina in the staple line, and it must be securely retracted out of the way as the two bowel ends are apposed (Fig 22.32c). The device is fired and removed. The 'doughnuts' of excised tissue from both bowel ends are removed from the stapler and checked to ensure that they are complete. The anastomosis is further checked for leaks by filling the pelvis with fluid, occluding the bowel above the pouch and introducing about 200 ml of air *per anum*. Bubbles appearing in the fluid-filled pelvis indicate a leak.

The pouch fills the cavity of the sacrum and reduces the pelvic dead space in which a haematoma can collect. This may reduce the incidence of anastomotic leak, as the spontaneous discharge of infected collections of blood into the bowel lumen, through the anastomosis, is believed to be a factor in the aetiology of a leak. Low-pressure suction drains may also be of value. These should be liberally primed with washout fluid, which is left in the pelvis at the end of the operation in order to prevent occlusion of the drain with clots. Any anastomosis where there is technical concern, and probably all coloanal anastomoses, are safer if they are protected by a temporary defunctioning loop ileostomy or colostomy.[16] Preoperative chemotherapy and radiotherapy will also make this anastomosis more vulnerable to leakage, and should influence the decision reached regarding a temporary stoma. A stoma should not be closed until a water-soluble enema has shown the anastomosis to be intact, without leakage, and a delay of 6–8 weeks is ideal (see p. 389).

Variations

Some surgeons prefer to use a per-anal, hand-sutured coloanal anastomosis in extremely low cases, and this technique is described in the section on ileo-anal pouches in Chapter 23, p. 423. An alternative to a small colon pouch is a stapled end-to-side anastomosis (Figure 22.33a). This also reduces faecal urgency when compared with a straight coloanal anastomosis, and the increased bulk in the pelvis during the immediate postoperative phase may also reduce postoperative pelvic collections and anastomotic leaks. Another alternative is a straight coloanal anastomosis with an anterior vertical enterotomy which is closed transversely (Figure 22.33b). Both colon pouches and end-to-side anastomoses have the additional advantage that the better-perfused side, rather than the end, of the colon is used for the anastomosis.

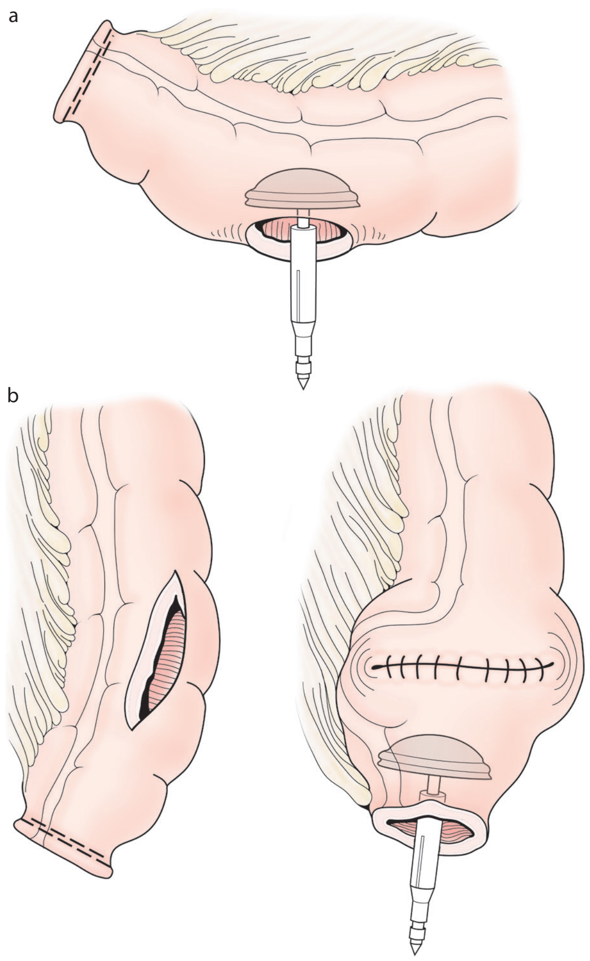

Figure 22.33 *(a) An end-to-side anastomosis. (b) An end-to-end anastomosis, but with a small colon pouch created by an anterior coloplasty.*

High anterior resection

This operation consists of transection of the mesorectum and preservation of the distal rectum. It may be performed in diverticular disease when a sigmoid loop is folded down and is adherent to the front of the rectum and cannot be safely released. A distal sigmoid tumour and the most proximal rectal tumours are also appropriate indications for this operation. It is essential, however, that 5 cm of mesorectum is excised beyond any tumour, and the surgeon must avoid 'coning in' through the mesorectum, as this results in compromised lymphatic clearance (see Figure 22.27). It is therefore still necessary to mobilise the rectum and the dissection is similar to that for a low anterior resection, except for the deepest parts of the dissection. The site of rectal division is chosen and, by dissection close to the lateral and then the posterior rectal wall of the bowel, a window is created between the rectum and its mesentery. In open surgery, the mesentery with the terminal branches of the superior rectal artery are then divided between artery forceps and ligated, while laparoscopically an energy device, such as the

Harmonic™ scalpel, is used. Access is difficult for a hand-sewn anastomosis, and a circular stapling device is usually preferred. A straight end-to-end or side-to-end colorectal anastomosis is satisfactory, but a colon pouch should not be used at this level as this can lead to constipation. A defunctioning stoma is not usually indicated unless there is some specific concern about the anastomosis.

Hartmann's procedure

In this operation, following a large bowel resection, the distal bowel is closed and left *in situ* and the proximal end is brought out as an end colostomy. After an anterior resection for rectal cancer, the surgeon may decide that a permanent stoma is wiser in a patient with very poor anal sphincters. In this situation, only an anorectal stump, closed by staples, is left *in situ* (Figure 22.34a). No later reconstruction is anticipated, but preservation of the anus avoids the additional morbidity associated with the perineal wound of an abdominoperineal excision of the rectum. An alternative in this situation, preferred by many surgeons, is to do an intersphincteric resection of the anorectal stump, with the external sphincter sutured to close the defect.

Although originally described as an operation for rectal cancer, Hartmann's procedure is now employed more frequently, in conjunction with an emergency sigmoid resection, for the complications of diverticular disease (see also Chapter 23). A Hartmann's has the advantage of shortening the operation and avoiding the risk of an anastomotic leak. However, restoration of continuity requires a second operation, which may not be straightforward. The alternative of a primary anastomosis with a temporary defunctioning proximal loop stoma should, therefore, always be considered, as the loop stoma can be closed as a much more minor second procedure compared with reversal of a Hartmann's.

When later restoration of bowel continuity after a Hartmann's procedure is anticipated, the distal bowel end should be marked with a non-absorbable suture, with the ends cut long, to make subsequent identification easier. A long stump may make reversal easier, especially if a hand-sewn anastomosis at open operation is anticipated.

REVERSAL OF A HARTMANN'S PROCEDURE

Reversal is often not in the best interests of the patient. The original decision not to restore continuity and the length of the rectal stump that has been left *in situ* are important factors in the decision-making process. Reversal should be delayed for 3–6 months to allow reduction in inflammation associated with the underlying pathology and the original operation. A long stump, which has been brought up to lie just beneath the lower end of the abdominal wound, will be relatively easy to identify at laparotomy, and a hand-sewn anastomosis will be practical. More often, the stump includes very little rectum above the peritoneal reflection, and although the operation may be straightforward, a number of difficulties may be encountered. The rectal stump must be identified, the end stoma dissected out and the two ends anastomosed (Figure 22.34b). The stump may be difficult to identify and access for a hand-sewn anastomosis can be limited without mobilisation of the rectum. Use of the circular stapling device does not always solve this difficulty. It may not pass up the rectal stump until rectal folds have been straightened out by mobilisation, and the defunctioned rectum may also have narrowed down and be unable to accommodate the stapler without splitting of the muscle tube. Restoration of continuity to a very short stump, as shown in Figure 22.34a, can be achieved relatively easily with a circular stapling device, but the empty pelvis may have adherent loops of small bowel and the initial dissection to free these can be tedious. In addition, the proximal bowel end may not reach down safely for the anastomosis until it has been further mobilised.

Reversal of a Hartmann's procedure can also be performed laparoscopically. All the abdominal dissection is undertaken

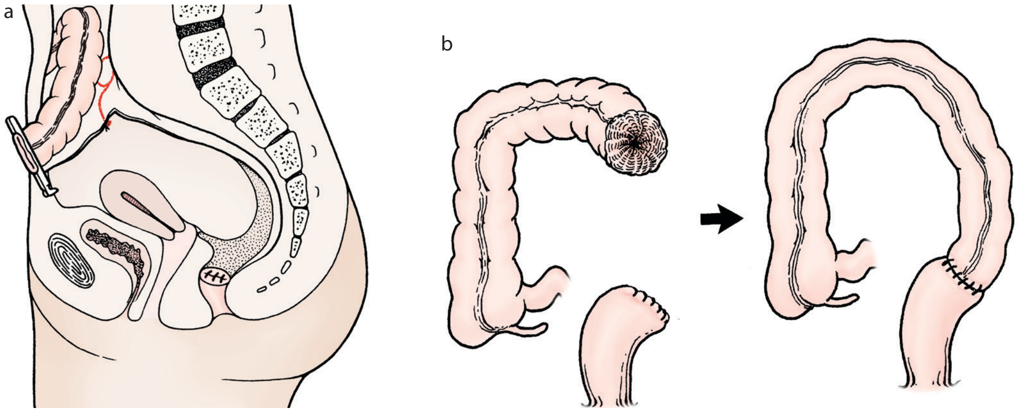

Figure 22.34 *Hartmann's procedure. (a) An end stoma is an alternative to restoration of bowel continuity after the anterior resection of a rectal cancer. Later restoration of continuity is then seldom undertaken. (b) After a sigmoid resection for diverticular disease a longer distal stump remains. If immediate anastomosis is contraindicated, later restorative surgery is usually considered.*

laparoscopically and the anastomosis is performed with the circular stapling device. Usually the end stoma is mobilised, the peritoneal cavity entered and pneumoperitoneum established using a seal at the stoma site. Conversion to an open operation may be required if extensive adhesions are encountered such that the surgeon is unable to mobilise safely laparoscopically.

Abdominoperineal resection

Abdominoperineal resection was the classic operation for both anal and rectal cancer, but the indications for this operation are dwindling. Squamous cell anal carcinoma is now managed by chemoradiotherapy and abdominoperineal resection is reserved for the occasional salvage situation. In rectal cancer, an abdominoperineal resection removed all the tissue around the rectum that was believed to be at risk of lymphatic involvement (see Figure 22.28) and, in addition, removed the anal stump, which was thought to be at risk of intramural tumour spread. In the light of present knowledge, there is therefore no oncological benefit in sacrificing the anus in the majority of rectal cancers, and in specialised centres the percentage of rectal cancers requiring abdominoperineal excision continues to fall. There are, however, some low rectal adenocarcinomas that are invading the anal sphincters or extending dangerously close to the plane of dissection at this level, and sacrifice of the anal sphincters becomes inevitable for a good oncological clearance (see Figure 22.31).

A separate issue is that of restoration of continuity after a low anterior resection. Before the advent of circular stapling devices, the difficulty of a hand-sewn anastomosis deep in the pelvis was a major deciding factor. Although it is now almost always technically possible to restore continuity after an anterior resection for an upper or mid-rectal tumour, it may still be inadvisable in a patient with very poor sphincter function. There is, however, no advantage in excising the anal canal and sphincters and inflicting an additional perineal wound. This situation is an indication for a low Hartmann's procedure or, alternatively, an intersphincteric resection of the anorectal remnant. However, as the deep aspects of an anterior resection for a lower-third rectal cancer can be technically very difficult and unnecessarily close to tumour, the surgeon may opt for an abdominoperineal resection if a restorative operation is felt to be contraindicated.

OPERATIVE PROCEDURE

The abdominal dissection is very similar to that for a low anterior dissection. It can be undertaken as an open or laparoscopic operation. The plane immediately outside the mesorectum is developed to mobilise the upper and mid rectum. This plane, however, should not be followed distally as it cones in below the mesorectum on the surface of the levators, or the circumferential margins will have been narrowed at the level of a low tumour (see Figure 22.31). Posteriorly, the dissection should stop when the pelvic floor musculature, with the overlying parietal pelvic (Waldeyer's) fascia, is first encountered. This is particularly important in cases where the tumour is either too low or too locally advanced for an anterior resection ever to have been an option. These tumours are below the mesorectum and their main protective covering is the 'cradle' of the levators.

The operation then continues from the perineum. An extra levator abdominoperineal excison (ELAPE), whereby the plane of excision is outside the levators, leaving the levators on the specimen, is now considered to be the optimal technique.[17] Turning the patient prone at this stage gives a better view.[18] If this is to be done, then the abdomen is closed and the end colostomy performed prior to turning the patient. The dissection commences with a purse-string suture, inserted just outside the anal verge, to seal the anus and prevent any contamination of the perineal wound with mucus or blood from the tumour. The anus is then circumscribed with an elliptical incision, and laterally the dissection enters the ischiorectal fat. The dissection is deepened posteriorly towards the coccyx, which is a palpable landmark for the surgeon. The initial entry through the pelvic floor is a transverse incision immediately in front of the tip of the coccyx, although the alternative of excising the coccyx with the specimen has the advantage of leading the surgeon more naturally into a radical clearance of the lateral pelvic floor. The midline incision must go through Waldeyer's fascia to enable the surgeon to insert a finger into the supralevator compartment of the pelvis. This step can be recognised by the arrival of blood from the abdomen into the perineal wound. Failure to break through this fascia results in stripping of the parietal fascia, with subsequent tearing of pelvic veins and autonomic nerve damage. Rotation of the hand allows the levator muscle to be steadied, between finger above and thumb below, while it is divided near its attachment to the pelvic sidewall and well lateral to the tumour and the sphincter complex (Figure 22.35a). The dissection is carried around on both sides.

Anteriorly in the male patient, the lower edges of the transverse peronei muscles are sought. The dissection should be immediately behind these muscles in order to enter the embryological plane between the rectal and urogenital structures. This plane can be difficult to define, and the surgeon is concerned, particularly in the case of anterior tumours, about obtaining adequate oncological clearance yet at the same time wishing to avoid damage to the urethral bulb. A urethral catheter is a useful guide at this point, as it can be palpated. If the perineal dissection is carried out supine, then the abdominal surgeon can guide the perineal surgeon into the correct plane, in the midline anteriorly, as the initial breakthrough into the supralevator compartment is made (Figure 22.35b). It is important that the anterior plane has been dissected adequately from above. Only the anterior pillars of puborectalis still remain intact. A finger is hooked around them and they are divided as far forward as possible. During the final anterior dissection, delivery of the specimen out through the perineal wound may be helpful.

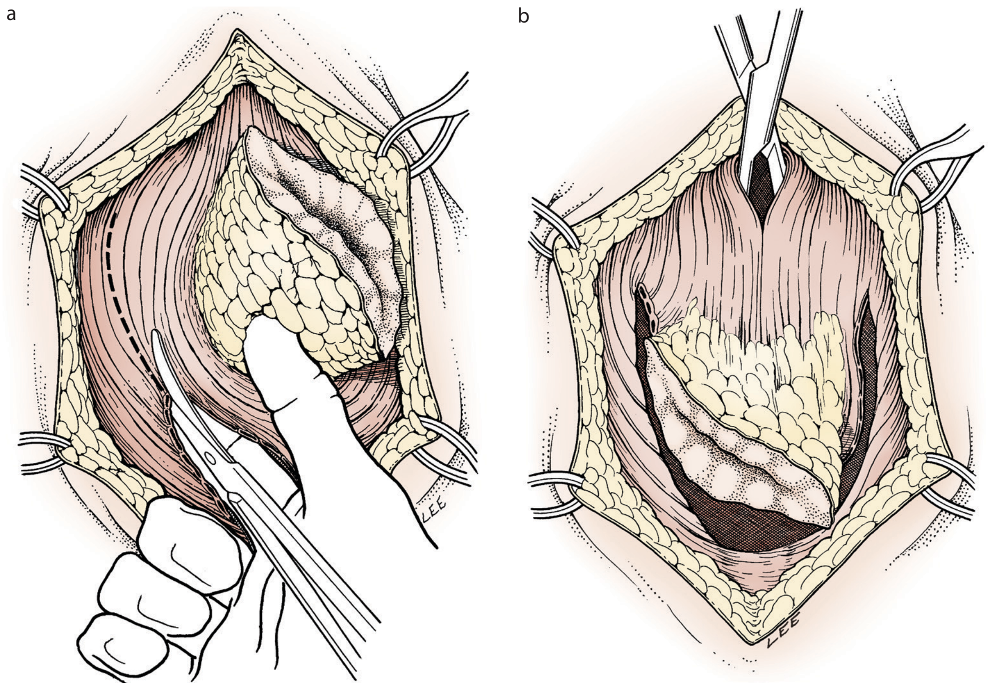

Figure 22.35 *The perineal dissection of an abdominoperineal excision of the rectum. (a) The fat of the ischiorectal fossa is entered and the incision deepened until the levator muscles are identified and incised well lateral to the bowel. (b) The perineal surgeon enters the supralevator compartment anteriorly in the midline. Only the anterior pillars of puborectalis remain to be divided.*

Anteriorly in the female patient, the plane between the vagina and rectum is difficult to follow, and part of the posterior wall of the vagina is often excised with the specimen. In anterior tumours this is a safer strategy oncologically.

Small bowel loops will tend to fill the empty pelvis, and late adhesion obstruction can be troublesome. The caecum can be mobilised and allowed to drop into the pelvis to exclude the small bowel and reduce this complication. Alternatively, the uterus will often lie retroverted following an abdominoperineal rectal excision and will naturally fill some of the pelvis. Some surgeons favour mobilising the omentum on a left gastroepiploic pedicle to bring it into the pelvis. Opinion is divided on the desirability of attempting to close the pelvic peritoneum, as closure may create a dead space below it. The problem of a dead space will be reduced if the fatty margins of the ischiorectal fossa can be drawn together with a few absorbable sutures around a vacuum drain, but this may not be possible after a wide resection. Finally, the perineal wound is closed.

Variations

A wide clearance of the perineal fat and skin may be necessary for an advanced tumour. Many of these patients have now routinely had preoperative radiotherapy or chemoradiotherapy, and there is substantial morbidity associated with delays in perineal wound healing. The wide surgical clearance may also predispose the patient to the development of a late perineal hernia. A flap, to bring well-vascularised muscle and skin into the perineum, may improve wound healing (see also Chapters 4, 13, 23 and 24). Rectus abdominis and gluteus maximus are both suitably placed for use in the perineum. The former is recommended when the perineal dissection has been performed without turning the patient, but a gluteus maximus myocutaneous rotation flap, raised either unilaterally or bilaterally, may be more appropriate when the perineal dissection has been performed in the prone jackknife position. The involvement of a plastic surgery colleague is recommended.

LARGE BOWEL RESECTIONS FOR BENIGN DISEASE

Large bowel resections for benign disease do not require the extensive mobilisation and resection of mesentery essential for colorectal cancer. The vessels may be ligated and divided adjacent to the bowel wall but, as multiple vessels are encountered at this level, a compromise is more often made (see Figure 22.2). The surgical options in inflammatory bowel disease, diverticular disease and volvulus are discussed further in Chapter 23.

A *right hemicolectomy* for benign disease of the caecum or terminal ileum requires a similar lateral peritoneal incision around the caecum, but mobilisation of the hepatic flexure off the duodenum and head of the pancreas is not required. Mobilisation need only be to a point where the relevant right colic and ileocolic vessels to the bowel to be excised can be isolated for ligation.

A *transverse colectomy* for benign disease does not require excision of the omentum, which can be dissected off the colon and retained. However, this is an unsafe plane to develop if the bowel is distended, inflamed and friable, and in this situation it should be excised with the colon, as for a radical resection.

A *sigmoid colectomy*, without a flush tie of the inferior mesenteric artery or a radical lymphadenectomy, may be performed for non-malignant pathology of the sigmoid colon. The initial dissection is similar to that for a radical left hemicolectomy, except that mobilisation of the splenic flexure is seldom necessary. The inferior mesenteric artery is identified. Its main trunk and its continuation as the superior rectal artery are preserved. The sigmoid mesentery is divided close to the bowel wall (see Figure 22.2). The anastomosis is then fashioned between the distal descending colon and the rectosigmoid junction. The blood supply of the rectum is secure and the distal resection line can be significantly above the peritoneal reflection. If, however, the resection is for diverticular disease, the distal resection line must be at a level where the taeniae have spread out to form the continuous longitudinal muscle of the rectum.

A *total colectomy*, performed for ulcerative colitis or familial polyposis coli, is the combination of the segmental colonic resections for benign disease. An ileorectal anastomosis can be performed or a terminal ileostomy fashioned. The rectal stump may then be closed or brought out as a mucous fistula at the lower end of the wound. Alternatively, the colectomy is combined with a rectal excision as a total proctocolectomy. Reconstruction with an ileoanal pouch is then possible.

A *proctectomy* for benign disease may be performed in a plane close to the rectal wall, leaving the mesorectum *in situ*. The potential for damage to the autonomic nerves is reduced, and the mesorectum retained in the pelvis is of value in filling the dead space. However, it is not a bloodless embryological plane, and many surgeons familiar with pelvic dissection prefer to follow the classic plane outside the mesorectum with only minor modifications, such as coning in lower down, to offer extra security to the autonomic nerves. These surgical options in inflammatory bowel disease are discussed in more detail in Chapter 23.

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23

OPERATIVE MANAGEMENT OF SMALL AND LARGE BOWEL DISEASE

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The standard techniques of intra-abdominal surgery and the classical intestinal operations have been described in the preceding chapters. There is often a range of surgical solutions available and the ability to choose the most suitable procedure increases with the surgeon's experience. Most frequently, surgeons choose the most appropriate of the classical operations relevant to the situation, but they should not be afraid of adaptations and modifications to standard procedures. It is extremely important, however, that any modifications are made within the framework of sound surgical principles.

SURGERY FOR INTESTINAL OBSTRUCTION

The initial management of any patient with an intestinal obstruction is correction of the fluid and electrolyte deficit by intravenous fluids, combined if possible with deflation of the bowel (see Chapter 12). A nasogastric tube is passed and the contents of the distended stomach are aspirated. The nasogastric tube is then attached to a bag and left on free drainage, in addition to intermittent aspiration. The small bowel becomes progressively deflated as the obstructed intraluminal contents reflux back into the stomach and are aspirated. A patient with a distal large bowel obstruction may benefit from nasogastric aspiration if there is additional distension of the small bowel, but otherwise it is of little value.

The next phase in the management is assessment of the patient and the decision as to whether emergency surgery is indicated. This decision hinges on the likelihood of an ischaemic or strangulated segment of bowel (see Chapter 15).

A firm diagnosis of the underlying pathology may be possible at this stage, but more often the surgeon continues with conservative treatment or plans an emergency operation with only a tentative diagnosis. Preoperative abdominal X-rays, however, should at least have helped to differentiate between small and large bowel obstruction. These are discussed separately, as the issues differ.

Small bowel obstruction

EXTERNAL HERNIAE

An *irreducible* external hernia must be sought in any case of small bowel obstruction. A reducible hernia is an incidental finding and not the cause of the obstruction. All hernial orifices must be checked, remembering that an irreducible femoral hernia is easily overlooked in the obese patient. A *strangulated* hernia is one in which the contents are constricted in such a way that the blood supply is impaired. An irreducible hernia causing a small bowel obstruction will usually quickly progress to a hernia with a strangulated loop of small bowel, and emergency surgery is indicated. A strangulated hernia in the absence of obstruction probably contains only omentum, but a *Richter's hernia* (Figure 23.1), in which only part of the circumference of the gut is trapped and the lumen is still patent, is a possibility. Colon, in contrast to small bowel, is seldom obstructed or strangulated within a hernia.

The hernia may be a spontaneous groin, epigastric or paraumbilical hernia, or it may be an incisional or parastomal hernia. The surgical approach and initial dissection are similar to those in an elective hernia repair (see Chapters 13 and 25). The hernial sac is then opened. Blood-stained fluid confirms strangulation of the contents and foul-smelling fluid suggests non-viable bowel. Contamination of the wound by this fluid should be minimised, as it will be heavily

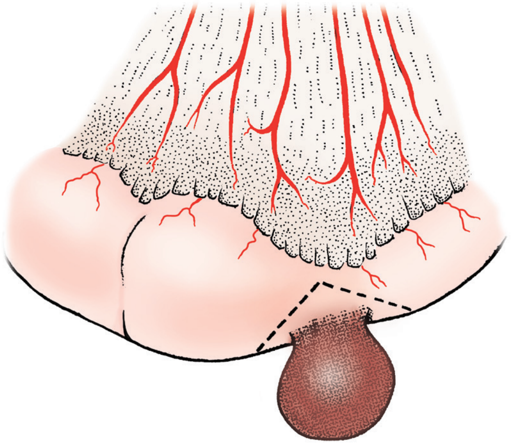

Figure 23.1 *A Richter's hernia. Only part of the circumference of the bowel is trapped, and strangulation can occur without obstruction.*

colonised with faecal organisms. The strangulating constriction must then be released in order to restore perfusion to the compromised contents (Figure 23.2). In an *indirect inguinal hernia* the constriction is usually the tight peritoneal neck of the sac, while in an *incisional hernia* it is more often the edge of the fascial defect, both of which are easily released. The strangulation in a *para-umbilical hernia* is frequently at the narrow neck of a loculus of the sac. A *femoral hernia* is constricted by the femoral ring itself; release is difficult and access poor from below. A minor release is possible by a medial incision into the lacunar ligament, but occasionally troublesome bleeding from an aberrant vessel is encountered. If release is inadequate, and especially if there is any concern over the viability of bowel in the sac, access from above is also necessary. If a low approach to the hernia has been made, an additional abdominal incision is usually required; either a midline incision or a low iliac fossa incision (see Chapter 25). If the bowel still cannot be delivered out of the hernial sac, it may be necessary to divide the inguinal ligament close to the pubic tubercle and reattach it afterwards.

If, on release of the constriction, the hernial contents quickly regain perfusion, a simple return to the peritoneal cavity and repair of the hernia is all that is required. The decision to resect is straightforward if no improvement occurs on releasing the constriction. If the surgeon is faced with doubtfully viable bowel and the abdomen is not open, it is unwise to replace the loop to aid recovery as it may be difficult to retrieve it again. Instead, it should be covered with a warm moist towel and left undisturbed for a few minutes.

Occasionally, a strangulated hernia reduces spontaneously, early in an operation, before the sac is opened. If, on opening the sac, blood-stained fluid is encountered, the surgeon must locate the bowel loop or omentum that had been trapped in order to check the viability of the strangulated tissue. A congested small bowel loop may be retrieved via the hernial neck and drawn back into the operative field for inspection, but a small laparotomy incision is often required in this situation.

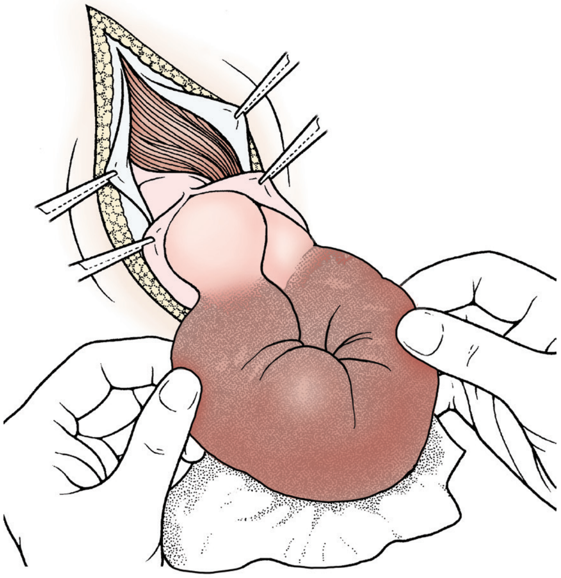

Figure 23.2 *A strangulated loop of small bowel in an inguinal hernia has been released by a peritoneal incision in the neck of the sac.*

In a ventral hernia, only an extension to the wound is required, but in a groin hernia a separate incision may be necessary.

Infarcted omentum is simply excised with a transfixion ligation just proximal to the termination of the viable tissue. A resection is mandatory for non-viable bowel and may be difficult because of limited access. In an adult strangulated inguinal hernia, a resection may be performed without opening the general peritoneal cavity. After completion of the anastomosis, the bowel is replaced within the abdomen and the peritoneum at the neck of the sac closed. If there is difficulty replacing the bulkier anastomosis through the deep ring, a lateral release of the ring may be necessary. This is a particular problem on the rare occasions when a bowel resection is necessary in a strangulated infantile inguinal hernia. A similar difficulty occurs after a resection for a strangulated femoral hernia approached through a low incision. This scenario should be anticipated and avoided by employing an additional separate abdominal incision for the resection and the anastomosis.

A non-viable loop of colon is fortunately relatively rare in a strangulated hernia, but if encountered will require a large bowel resection of obstructed colon, as discussed later in this chapter. A major laparotomy incision is mandatory for adequate access.

ADHESION OBSTRUCTION

The commonest cause of small bowel obstruction is an adhesion obstruction with a loop of small bowel compressed, kinked or twisted by an adhesion following previous surgery. Any patient with an abdominal scar or a history of a vaginal hysterectomy can be presumed to have an adhesion obstruction of the small bowel in the first instance, provided that a strangulated external hernia has been excluded. Deflation with a nasogastric tube may be sufficient to allow the situation to resolve, and no surgery is then indicated.

Closed loop adhesion obstruction is a variant of the common small bowel obstruction. It may be a closed loop from the start if a small bowel loop has twisted around a band. Alternatively, it may start as a simple obstruction, but subsequent dilatation and displacement of bowel loops can cause a second, more proximal obstruction. Once a closed loop obstruction has occurred, it cannot be decompressed from above by nasogastric aspiration. Distension increases and the bowel becomes ischaemic from excessive intramural pressure, even in the absence of a twist in the mesentery. The distended loop, however, often does rotate, with resultant occlusion of the mesenteric vessels, which then becomes the most important factor in the ischaemia of strangulation.

An ischaemic loop causes continuous abdominal pain in addition to the colic of obstruction. A careful history may elicit this symptom, and examination should demonstrate peritoneal irritation. It must be remembered, however, that in full-thickness inflammatory small bowel conditions causing obstruction (e.g. Crohn's disease), peritoneal inflammation does not necessarily indicate ischaemia, and continuing conservative management, despite local peritonism, may be appropriate. A rising pulse rate and a leucocytosis are markers of the systemic inflammatory response to an ischaemic loop of bowel and are useful monitoring parameters during the conservative management of a small bowel obstruction. Urgent surgery is indicated whenever strangulation is suspected.

In a simple obstruction, with no indication of strangulation, conservative management may be continued for several days but, if no resolution is occurring, surgery should be planned. A water-soluble small bowel contrast study may be valuable in distinguishing obstructions that will resolve from those requiring surgery. For example, Urografin® (40 ml in 40 ml of water) can be administered orally or via a nasogastric tube, and the patient X-rayed 4-hourly to detect contrast medium reaching the caecum. The technique, however, often produces the answer without the need for X-rays, as the patient either passes flatus and diarrhoea or becomes more distended and experiences increased pain.

A small bowel obstruction with no previous surgery is unlikely to be due to adhesions. Congenital adhesions, inflammatory adhesions from previous diverticulitis or gynaecological pelvic inflammatory disease and adhesions from blunt abdominal trauma remain possibilities, but some other intra-abdominal pathology, especially malignancy, is increasingly likely. In the absence of symptoms or signs of strangulation, emergency surgery is not necessary and initial treatment can be conservative. Surgical intervention is, however, usually required and should not be unnecessarily delayed.

A postoperative small bowel obstruction can be difficult to differentiate from an ileus and surgeons must be alert to the possibility of bowel trapped in a port site hernia.[1] A mixed picture of small bowel obstruction and ileus is also sometimes encountered postoperatively. This was common after appendicectomy before antibiotics were used routinely, and often occurred after an initial return of bowel function. It is usually associated with intra-abdominal inflammation or abscess formation. If there is a significant collection of pus, drainage is required, but otherwise treatment should be conservative. The loops of oedematous small bowel involved in the inflammatory process will recover with rest and antibiotics. Intravenous feeding is often indicated if recovery is prolonged. Surgery should ideally be avoided as it carries a considerable risk of damage to friable bowel.

Prevention of adhesion obstruction

Adhesions are a major cause of late morbidity.[2] They may occur after any intraperitoneal intervention, but are unpredictable, as some patients have multiple operations and produce minimal adhesions. However, the risk does depend on the type of surgery, with a total colectomy carrying one of the highest risks of approximately 30 per cent incidence of small bowel obstruction within 10 years. Any agent that reduces adhesions may also reduce serosal sealing of an anastomosis, with the potential to increase anastomotic leakage.

It has long been noted that many patients form extensive soft pliable adhesions between loops of small bowel. These adhesions prevent free mobility of the loops, without predisposing to obstruction. Surgical attempts to mimic this with plication techniques in patients experiencing repeat small bowel obstruction have not been generally successful.

Surgery for small bowel obstruction

General anaesthesia must be combined with protection of the airway from inhalation of vomit. Either laparoscopic or open surgery may be suitable. Significant small bowel distension will make laparoscopy more difficult, and a decision to convert to open surgery may be prudent, especially if widespread adhesions are encountered. On entering the abdomen the cause of the obstruction may be immediately obvious, but more often nothing can be seen initially except distended loops of small bowel, which should be displaced to the left so that the caecum can be inspected.

A *collapsed caecum* confirms the presence of a small bowel obstruction, as the *caecum is distended* when the obstruction is in the large bowel. A search is made in the right iliac fossa and pelvis for a collapsed loop of bowel. (If there is a *collapsed caecum but no collapsed distal ileum*, the obstruction is very close to the ileocaecal valve and is almost certainly a carcinoma of the caecum. Unfortunately, this is frequently found to be the cause of a small bowel obstruction in an older patient.) When collapsed ileum is identified it is traced proximally until the obstruction is reached. A single adhesion can then be simply released, but often both the collapsed and the dilated loops are bound by multiple adhesions, which must also be freed. This can be a tedious process, especially if loops of distended bowel are adherent in the pelvis. Extreme gentleness is essential as tears in obstructed tethered small bowel loops, deep in the pelvis, make further mobilisation increasingly difficult, especially as an inadvertent enterotomy often cannot be repaired, or even fully controlled, until the loop is freed. Distended loops of bowel should, if possible, be retained within the abdomen but, if this is not possible, they should be covered with a warm moist pack and supported to prevent undue traction on the mesentery.

If a loop of strangulated bowel is encountered, a decision on viability must be made. Grey or black bowel with a lustreless, flaccid sodden wall is obviously non-viable and must be resected. The mesenteric vessels to the loop should ideally be clamped before any release of a constriction or any untwisting of a volvulus is undertaken. This prevents restoration of circulation through the dead tissue and the inevitable release of toxic metabolites into the circulation. (This is unfortunately seldom possible when infarcted bowel is found in a strangulated external hernia, as access to the mesentery is initially so limited.) More often, the viability of the strangulated loop is uncertain and perfusion must first be restored. The decision may then be easy if there is either a rapid recovery or no improvement, but if there is still doubt, the loop should be left undisturbed within the peritoneal cavity for 5 minutes before reinspection. On occasion, the loop is viable except for two narrow non-viable bands at the site of the constriction; these can be safely invaginated with seromuscular sutures.

Even if the obstruction has only required a simple release, closure of the abdomen after a laparotomy may be difficult until further small bowel deflation has been achieved. This can be done by 'milking' back the small bowel contents into the stomach, from where they can be aspirated through the nasogastric tube by the anaesthetist (Figure 23.3). Alternatively, a needle aspiration (see Chapter 14, p. 230) may be a useful manoeuvre.

Surgery may demonstrate a small bowel obstruction secondary to some underlying pathology that requires to be addressed in its own right.

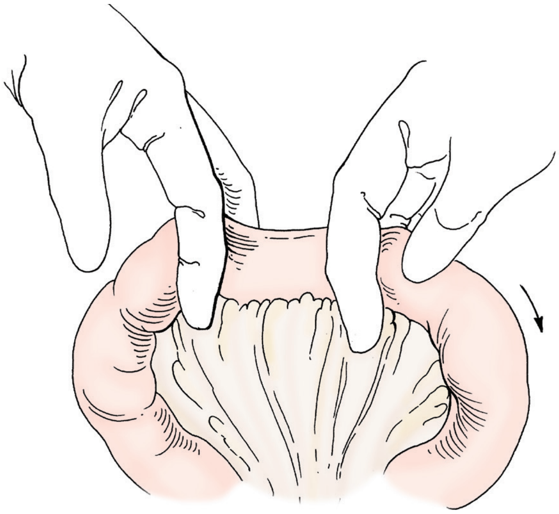

Figure 23.3 *Gastrointestinal contents can be 'milked' from a dilated segment of bowel into a segment from which they can be removed.*

INTRALUMINAL OBSTRUCTIONS

An impacted ingested foreign body or a gallstone can be removed by simple enterotomy. In *gallstone ileus* this is adequate definitive treatment. The fistula between the biliary tract and the small intestine is serving a similar purpose to a therapeutic sphincterotomy and, as an associated cholecystectomy may be difficult and potentially dangerous, only an experienced biliary surgeon should consider proceeding further.

Ascaris lumbricoides infestation can produce an obstruction from a bolus of worms. Management of the obstruction is conservative and deworming should be postponed until the obstruction has resolved. If a laparotomy has been performed, an enterotomy is normally avoided for fear of migration of worms through the suture line; fortunately, it is usually possible to 'milk' the worm bolus through into the caecum.

BENIGN STRICTURES

The operative decisions in benign strictures depend on the aetiology. Fibrous strictures can be treated by stricturoplasty or simple resection. Strictures associated with Crohn's disease and tuberculosis are discussed below. A radiotherapy stricture causing obstruction requires a resection that includes the adjacent bowel, which has inevitably also been damaged by the radiotherapy. If this is not done, the anastomosis will be performed with compromised tissue and there is a high risk of anastomotic breakdown.

INTERNAL HERNIAE

An internal hernia may involve only a partial circumference knuckle or a short segment of small bowel trapped beneath a peritoneal fold or within an obturator defect. The bowel is released, resected if non-viable and the space in which it was trapped obliterated or repaired. The herniation may, however, represent a more serious form of the closed loop obstruction discussed above. The greater part of the small bowel may have herniated through a mesenteric defect, the anatomy is difficult to elucidate and release of the constriction must be cautious or mesenteric vessels at the edge of the defect will be damaged.

Strangulated stomach within a hiatus hernia and strangulated colon through an old diaphragmatic laceration are further potentially serious forms of internal herniation.

SMALL BOWEL VOLVULUS

A small bowel volvulus may endanger the perfusion of the whole small bowel. Those that occur in infancy are commonly associated with congenital intestinal malrotation or occur around a vitello-intestinal duct remnant attached to the abdominal wall. Adult small bowel volvulus is a common condition in some parts of the world, where it is sometimes encountered around the base of a sigmoid volvulus to produce a complicated 'sigmoid knot'.[3] The operation consists of release of the constriction by derotation, first of the loops of small bowel, followed by the large bowel. Any non-viable portions are resected.

INTUSSUSCEPTIONS

The apex of an intussusception usually lies in the ascending or transverse colon, and consists of an area of abnormal ileum. Operative reduction of an intussusception is by repetitive gentle squeezing of the bowel just distal to the apex, which moves progressively more proximal as the intussusception is reduced. Reduction by traction is liable to cause damage. If reduction is not possible, a resection is necessary, most often in the form of a right hemicolectomy. After a successful reduction, a resection may still be necessary if the bowel is infarcted or if it has torn during reduction. In addition, in adult patients the apex is commonly a small bowel tumour, which requires a resection with inclusion of its lymphatic drainage. The common infantile intussusception can usually be managed non-operatively and is discussed further below.

SMALL BOWEL TUMOURS

The surgery of these relatively uncommon tumours is resection with a generous '**V**' of mesentery in order to obtain a radical lymphadenectomy. The tumour may be an adenocarcinoma, a carcinoid or a lymphoma. It is important to check the whole small bowel carefully for additional tumours, as carcinoids are frequently multiple (see Chapter 16).

MALIGNANT ADHESIONS AND PERITONEAL DEPOSITS

A patient presenting with a small bowel obstruction may have a loop of small bowel adherent to a previously undiagnosed intra-abdominal malignancy. If the primary tumour is resectable, the only chance of cure, and usually the best palliation, is achieved by a radical resection of the primary tumour *en bloc* with the involved loop of small bowel (see Figure 16.2, p. 256).

A patient with multiple peritoneal malignant deposits may present with a small bowel obstruction. One, or more, side-to-side anastomoses may relieve the obstruction, but often little can be achieved by surgery (see also Chapter 16).

Large bowel obstruction

Many large bowel obstructions pose no immediate threat to bowel wall viability. Urgent, rather than emergency, surgery is therefore indicated and a delay of 24–48 hours for further assessment can be beneficial. The rectum must be checked digitally, and by sigmoidoscopy, for an obstructing rectal cancer and also for any synchronous pathology. On plain X-ray, a *pseudo-obstruction* cannot be differentiated from a mechanical distal large bowel obstruction. As pseudo-obstruction is almost always better managed conservatively, it must be excluded preoperatively. The level of a distal obstruction can also be difficult to interpret on preoperative X-ray, as dilated loops of mobile sigmoid colon may be folded down into the pelvis. A CT scan or a water-soluble rectal contrast study is therefore advisable during this period of assessment, whether a distal large bowel obstruction is thought clinically to be mechanical, or not. This should differentiate a pseudo-obstruction from a mechanical obstruction and should also indicate the level of the latter.

In some patients who are only partially obstructed, conservative management may allow at least temporary resolution. Endoscopic or radiological confirmation of the diagnosis is then possible, followed by surgery under more favourable elective conditions a week or two later. Another option is the use of a temporary endoluminal stent to relieve a malignant large bowel obstruction and allow definitive surgery to be undertaken in a truly elective situation after full investigations and bowel preparation. This technique may, however, cause peritoneal contamination with tumour cells if the dilatation causes serosal splits in the tumour. A stent, however, is an ideal solution for a patient with a malignant distal large bowel obstruction and inoperable intraperitoneal or hepatic metastases. If the diagnosis and staging can be established preoperatively, a major resection or a stoma can sometimes be avoided altogether.

In benign pathology, surgery can also occasionally be avoided. A sigmoid volvulus may be decompressed endoscopically and, in an unfit patient, an expectant policy may be a safer option than surgery to prevent possible recurrences. Sigmoid diverticulitis may cause an obstruction that is difficult to differentiate from one caused by a sigmoid cancer. When an obstruction is incomplete and there is evidence of inflammation in the left iliac fossa, a diagnosis of diverticulitis is favoured and management is initially conservative with antibiotics. The obstruction will often resolve, but further investigation, after the acute episode has settled, is important to exclude a cancer, as inflammation can also occur around a locally perforated tumour. Absence of inflammation does not exclude a simple fibrous diverticular stricture associated with long-standing disease. Most patients who have had an episode of obstruction associated with diverticular disease should be advised to have a resection, but in an unfit patient this may again be an unacceptable risk.

Occasionally, the surgeon may be forced to operate within a few hours of presentation when there is evidence of ischaemia developing in the obstructed colon. For example, in a large bowel volvulus there is a blind loop obstruction with additional torsion of mesenteric vessels. The risk of strangulation, with colonic infarction, is high, and urgent resolution is important, as discussed below. A simple distal large bowel obstruction can also develop into a dangerous closed-loop situation if the ileocaecal valve is competent, preventing reflux of intestinal contents into the ileum. Progressive large bowel distension is rapid and the increasing intraluminal pressure and distension threaten the perfusion of the colonic wall (see Chapter 12). Caecal rupture finally ensues. This should not occur in a patient already in hospital, as the deteriorating situation, with increasing distension and tenderness of the caecum, should have been noted.

Surgery for large bowel obstruction

Whether an open or a laparoscopic operation is chosen will depend on the surgeon's preference, in addition to the level of the obstruction, the likely pathology and the degree of bowel distension. If the obstruction is left sided, the patient should be positioned with 'legs up' to afford access to the anus. The rectum must be assessed in theatre by digital and rigid sigmoidoscopic examination, if this has not already been done, as even if the obstruction is known to be more proximal, a small synchronous lesion in the rectum must be excluded. Additionally, a rectal obstruction can be mistaken at operation for a pseudo-obstruction. It is therefore essential to check that any distal bowel to which access for inspection and palpation is difficult from above has been fully examined from below.

If the ileocaecal valve is patent, there may be gross small bowel distension in addition to large bowel distension. Even in an open operation through a generous midline incision, deflation may be necessary before further exploration is possible. A sucker can be introduced into both the ileum and the caecum through a small incision in the distal ileum, controlled by a purse-string suture. This can be very helpful in reducing gaseous distension; however, in the colon the sucker tends to block quickly with semi-solid faecal matter, and it is easy to cause gross peritoneal faecal contamination during this manoeuvre.

The operative strategy in a large bowel obstruction then depends on the underlying pathology and the site of the obstruction.

MALIGNANT LARGE BOWEL OBSTRUCTION

Malignancy is the commonest cause of a large bowel obstruction in the Western world. Many of these tumours are still potentially curable, and a major radical resection, as described in Chapter 22, is required. Stents should be considered preoperatively for left-sided lesions, but when an irresectable tumour is found at surgery, a proximal loop stoma may be the only practical solution. However, a bypass should be considered as it avoids the distress of a stoma (see Figures 22.20, p. 394 and 22.26, p. 399).

Right hemicolectomy

Right colon tumours are treated with a standard radical right hemicolectomy. The presence of obstruction is seldom a major problem during mobilisation and the small bowel is deflated by intraluminal suction through the divided ileum prior to the anastomosis. The more distal colon is relatively empty and an ileocolic anastomosis is safe in obstructed bowel. A transverse colectomy is unsuitable in an obstructed colon and an obstructed transverse colon cancer should be treated with an extended right hemicolectomy so that the ileum is anastomosed to the descending colon. In an attempt to use ileum in a safe anastomosis, this concept has been extended as a subtotal colectomy and ileorectal anastomosis for obstructing carcinomas of the descending colon or sigmoid. If this resection is chosen, the surgeon must keep in mind the segment of colon that requires the radical lymphadenectomy (see Figure 22.2, p. 378). This operation has great advantages if the viability of the caecum from distension is in any doubt. However, if the caecum is healthy, a safer anastomosis has been created at the expense of the loss of a large proportion of healthy colon, and some patients will be left with troublesome diarrhoea.

Left colonic resections

Left colonic resections carry a high morbidity when undertaken for obstruction. The mobilisation of left-sided tumours can be technically challenging with obstructed, dilated bowel. In addition, a primary anastomosis is compromised by alterations in the colonic wall secondary to distension. Local infection or faecal peritonitis will further increase the anastomotic vulnerability, as does the poor general state of an ill or elderly patient.

Previously, a simple defunctioning right transverse colostomy was recommended to relieve a left colonic obstruction, and definitive surgery was undertaken at a later date. A primary resection is now considered preferable, but should not be performed by an inexperienced surgeon in suboptimal conditions during the night. Fortunately, most surgery for malignant large bowel obstruction can be safely delayed for 24–48 hours and performed under more ideal circumstances. If intervention has proved unavoidable in difficult circumstances, there may still be a role for a simple defunctioning colostomy. For example, a tumour of the splenic flexure can be technically difficult to mobilise if the gut is distended. The surgeon may believe that it is in the best interests of the patient to bring out a defunctioning stoma and delay the resection so that it can be carried out under elective conditions by a surgeon with more colorectal experience. An advanced obstructed tumour of the upper rectum (as discussed later) should often not be excised as an emergency procedure, even by an experienced colorectal surgeon. A proximal loop colostomy, followed by full assessment and preoperative radiotherapy, may give the patient a better prognosis.

In most situations, however, it is possible to perform an oncologically sound radical resection of a primary left colon tumour at the initial operation for obstruction and, if so, this is the ideal management. If the tumour is resected as an extended right hemicolectomy or a subtotal colectomy, a low-risk ileocolic or ileorectal anastomosis can be performed. However, if a standard radical left hemicolectomy has been performed, the choice is between a Hartmann's procedure or a high-risk anastomosis. The advantages of the speed and lower risk of Hartmann's procedure are offset by the necessity of a further major operation to rejoin the bowel if the patient is unhappy with a permanent stoma.

When a reconstruction is planned after a left colonic resection for obstruction, the surgeon should consider the potential benefit of emptying the proximal colon prior to an anastomosis, and of protecting the anastomosis with a proximal loop stoma. Closure of this stoma 6 weeks or so later is a small procedure compared with the operation to reverse a Hartmann's procedure.

On-table large bowel lavage. This is the most satisfactory method of emptying the obstructed colon of faeces.[4] A catheter is inserted into the ileum through a purse-string suture and advanced through the ileocaecal valve into the caecum. Alternatively, the appendix is removed and the catheter is inserted into the stump. The appendix stump is ligated when the irrigation is completed. The colon is divided above the obstruction and the end of the bowel is either placed outside the abdomen directly into a bowl, or connected to a length of tubing (as shown in Figure 23.4) if there is insufficient length. Fluid is then run through the catheter until the bowel is empty of faecal material. However, the importance of an empty colon is now challenged and the increased risk of leakage in obstructed cases is probably due to changes in the bowel caused by distension.

DIVERTICULAR OBSTRUCTION

When the diagnosis is certain at operation, the narrow area of bowel is excised by a sigmoid colectomy and there is no need for a radical lymphadenectomy. However, a surgeon often has to operate for a sigmoid obstruction of uncertain aetiology, and the resection should follow the steps for a radical resection if cancer cannot be excluded. Following the resection, the choice is again between a Hartmann's procedure and the re-establishment of colonic continuity.

VOLVULUS

Sigmoid volvulus

A sigmoid volvulus is the commonest cause of large bowel obstruction in parts of Africa and Asia, where it occurs in all age groups. In Europe and North America it is primarily a condition of the elderly. Diagnosis of sigmoid volvulus and the less common caecal volvulus is made on the classical X-ray appearance. A large bowel volvulus requires urgent release and, if the sigmoid is involved, this can usually be achieved endoscopically. Recurrence is a problem, but major emeregency surgery in an elderly patient has been avoided. An endoscopic two-point fixation of the sigmoid loop using a percutaneous endoscopic gastrostomy (PEG) device is a compromise that may be worth considering in the elderly.

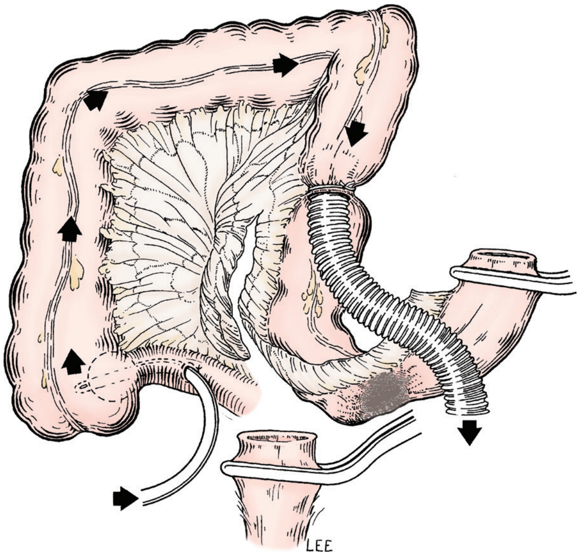

Figure 23.4 *An on-table colonic wash-out.*

If a sigmoid volvulus cannot be decompressed endoscopically or if there is concern over sigmoid viability, then laparotomy is essential. A viable sigmoid may be simply untwisted, but recurrence is likely. Attempts to fix the sigmoid to prevent recurrence are not always successful, nor are the ingenious attempts to plicate or widen the sigmoid mesentery.

However, the surgeon faced with a frail elderly patient wishes to avoid not only the risks of resection but also the danger of recurrent volvulus and the need for later elective surgery. It may then seem reasonable to attempt such a manoeuvre. By contrast, in the fit patient a sigmoid resection is the preferable option. A resection is also mandatory if the sigmoid has infarcted. Control of the vascular pedicle, before untwisting, will reduce the venous drainage of toxins into the circulation but may not be technically possible. A sigmoid colectomy is performed with preservation of the superior rectal artery. The surgeon then has three choices:

- A primary anastomosis, with or without on-table lavage, and with the option of a proximal loop stoma. A primary anastomosis without a proximal temporary stoma is usually safe in young and otherwise fit patients.
- The proximal end can be brought out as an end colostomy and the distal end can be brought to the surface as a mucous fistula. If they are adjacent, reanastomosis is then a more minor undertaking. However, there is seldom sufficient length in the distal limb to achieve this.
- The distal end can be closed as a Hartmann's procedure and an end colostomy formed. A second major operation will be required if the patient wishes bowel continuity to be restored.

Caecal volvulus

A caecal volvulus is best treated with a right hemicolectomy, even if the bowel is viable, as attempts at caecopexy seldom prevent a recurrence. If fixation is to be attempted, the caecum can be sutured to parietal tissue or it can be tethered by a caecostomy.

Pseudo-obstruction

Pseudo-obstruction is difficult to differentiate from a distal large bowel obstruction, and a diagnosis should not be made without a confirmatory distal contrast study to exclude a mechanical cause. Pseudo-obstruction occurs classically in the ill and elderly and is particularly common in orthopaedic inpatients who have had recent hip surgery. There is an overlap with sigmoid volvulus and some patients have a history of both conditions. It is thought that the colonic distension of a pseudo-obstruction may predispose to a volvulus.

Treatment

Surgery can usually be avoided by endoscopic deflation. Alternatively, neostigmine (2.5 mg dissolved in 50 ml of saline) is given intravenously over 3–5 minutes. If ineffective, the treatment can be repeated after 20 minutes. A dramatic response is common, but the cardiovascular effects of the treatment must not be underestimated and full resuscitation facilities should be available. Failure of these methods or caecal distension, which jeopardises viability, will necessitate surgery. More often, the abdomen has been opened on a preoperative diagnosis of a mechanical obstruction. The surgical options depend on the viability of the caecum and the probable precipitating causes of the pseudo-obstruction.

If the caecum is gangrenous, a right hemicolectomy with an ileocolic anastomosis is a possibility, but the back-pressure on the anastomosis is worrying if the pseudo-obstruction persists. The alternative of a right hemicolectomy with a terminal ileostomy is safer, especially if the caecum has already ruptured. Distension of the distal bowel, however, may recur; this makes closure of the distal end hazardous, and it should be brought out as a mucous fistula (see Chapter 22). If the caecum is viable at laparotomy, a tube caecostomy is a useful temporary solution in patients who have a background of normal bowel function and an obvious precipitative cause of the episode of pseudo-obstruction. In patients with longstanding problems of bowel motility, a caecostomy should be avoided, as it merely adds another complication to their already difficult long-term management.

CAECOSTOMY

A caecostomy does not provide adequate drainage of an obstructed colon, nor does it afford useful protection of an anastomosis.[5] However, it can be a temporary life-saving method of colonic deflation in a patient with threatened caecal rupture whose general state precludes any immediate more major intervention.

An appendicectomy incision is made under local or general anaesthesia. The caecum presents on opening the peritoneum. The gaseous distension is relieved by needle puncture through an anterior taenia. This portion of caecum can then be drawn out of the wound, and a purse-string suture inserted through which a self-retaining catheter is passed into the caecum (Figure 23.5). The purse-string suture is tied and the catheter is brought out through a separate stab incision and secured with a skin suture to hold the caecum firmly against the anterior abdominal wall.

Postoperatively, a caecostomy tends to block with faecal matter and must be flushed regularly if it is to be of any benefit. Hourly flushing with 50 ml of saline is recommended in the acute situation. After 2 weeks the tube can be removed without fear of peritoneal faecal contamination and, in the absence of a persisting distal anatomical or functional obstruction, the fistula heals within days.

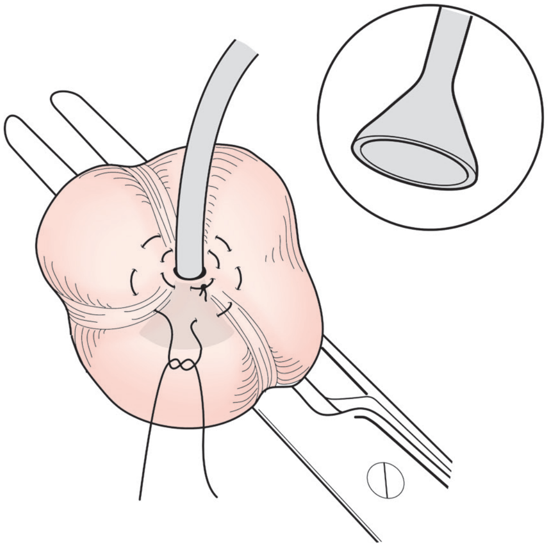

Figure 23.5 *A soft clamp prevents contamination until the catheter is firmly secured. The most suitable catheter is a de Pezzer with the end cut off, as shown in the inset.*

SURGERY FOR LOWER GASTROINTESTINAL TRACT HAEMORRHAGE

Occasionally, the cause of profuse lower gastrointestinal haemorrhage is obvious; the patient may have severe colitis or a history of a recent haemorrhoidectomy. More often, the underlying pathology is obscure. The patient is classically middle-aged or elderly, and the most common source of the haemorrhage is either an eroded vessel at the neck of a sigmoid diverticulum or an ulcerated angiodysplastic lesion in the submucosa of the right colon. A spontaneous large haemorrhoidal bleed is another possibility. A major proximal gastrointestinal haemorrhage can also result in fresh blood at the anus, and must be excluded.

Treatment

The first priority is adequate resuscitation followed by gastroscopy to exclude upper gastrointestinal pathology. Any anti-coagulation must be reversed. Surgical intervention can usually be avoided as 90 per cent of patients with profuse lower gastrointestinal haemorrhage will stop bleeding spontaneously. The cause of the haemorrhage may never be elucidated, even after extensive investigations, but it seldom recurs.

A *colonoscopy* is of little help as the blood obscures the view. A *flexible sigmoidoscopy*, undertaken without a prior enema, can sometimes be helpful. If the sigmoidoscope can be passed into the colon proximal to the luminal blood to where there is normal stool, this indicates that the bleeding is from the anus or rectum. This information has prevented the occasional inappropriate colectomy for severe haemorrhoidal bleeding.

If profuse bleeding continues and surgery seems inevitable, a preoperative angiogram can be performed to elucidate the site of the bleeding, as this often remains obscure even at laparotomy. CT angiography is an alternative diagnostic test to conventional angiography, but does not allow embolisation if a bleeding vessel is seen. It may, however, be more readily available as no arterial catheterisation is required. Embolisation must be precise and distal in the arterial tree or there is an increased risk of a patch of non-viable colon developing and rupturing several days later. Angiography will only be helpful if bleeding is occurring at a rate greater than 0.5–1.0 ml per minute. Unfortunately, although the bleeding is usually intermittently much faster than this, angiography performed between brisk bleeds will add no information.[6]

If angiography is unavailable or is unhelpful, the surgeon may be forced to operate without a diagnosis. Occasionally, a bleeding Meckel's diverticulum or other obvious pathology is identified, but more often there is no visible or palpable evidence of the site of bleeding. Mild diverticular disease of doubtful significance is noted, and the whole colon is full of blood. Blood in the right colon does not confirm a more proximal source of haemorrhage as it may have refluxed from the left side. The differential diagnosis is thus still between angiodysplastic bleeding, which is more common from the right colon, and diverticular bleeding from the left. A blind right or left hemicolectomy leaves the patient at high risk of requiring a second major laparotomy within 48 hours. A subtotal colectomy and ileostomy is now the recommended procedure in this situation. The risk of further haemorrhage is significantly reduced, but at the expense of a more major initial resection. A second elective laparotomy is still required to restore intestinal continuity with an ileorectal anastomosis. In the meantime, however, if there is a further haemorrhage, it will be obvious whether it is from the rectum or from the proximal gastrointestinal tract.

A transverse 'split colostomy', in which the two ends of the divided transverse colon are brought out as separate stomas with an intact skin bridge between, can occasionally be a useful diagnostic measure in a patient who has temporarily stopped bleeding but in whom the aetiology remains obscure. Any subsequent haemorrhage will then immediately identify whether the bleeding is from the right or left colon. A further laparotomy for a hemicolectomy will probably be required, but the patient will not need to lose the whole colon.

ISCHAEMIC INTESTINAL CONDITIONS

Ischaemia secondary to external compression of mesenteric vessels from a volvulus and the strangulation of bowel within a hernia has already been discussed, as has the intramural ischaemia of excessive dilatation. Ischaemia can also occur secondary to a mesenteric embolus or thrombus or as a consequence of primary vascular pathology.

Chronic mesenteric ischaemia due to an atheromatous stenosis of the superior mesenteric artery (SMA) or other visceral artery may be amenable to angioplasty or surgical reconstruction, as discussed in Chapter 7.

Acute mesenteric ischaemia presents as an intra-abdominal intestinal emergency and the mortality is high, especially as laparotomy is seldom performed before bowel infarction. Presentation is variable, but pain and elevation of the white cell count are often disproportional to the clinical findings. Sudden arterial occlusion of the SMA is either from an embolus or from a thrombus on a pre-existing stenosis at the origin of the artery from the aorta. Venous occlusion is almost exclusively from mesenteric venous thrombosis.

MESENTERIC EMBOLUS

Mesenteric embolus should be suspected in any patient with an acute abdomen who is in atrial fibrillation. Other potential sources of embolus include mural thrombus in the heart after a myocardial infarction and atheromatous plaques in the proximal aorta. At laparotomy, pulsation is classically preserved in the proximal SMA, and the ischaemia does not extend the whole length of the bowel supplied by the artery. This is because the embolus lodges where the artery narrows after it has given off the middle colic artery and the first of its jejunal branches. Infarcted bowel must be resected, but ischaemic bowel can be reperfused. The artery is isolated at the root of the small bowel mesentery, as approaching it flush with the aorta is very difficult. An embolectomy is preferaby performed via a longitudinal rather than a transverse arteriotomy as although it will probably require a vein patch for closure, its orientation does not compromise the distal anastomosis of a salvage bypass graft if this proves necessary.

Patchy, widespread necrosis due to multiple emboli either from an ulcerated plaque within the SMA itself or from the adjacent aorta is a particularly difficult situation, often requiring multiple laparotomies.

MESENTERIC ARTERIAL THROMBOSIS

This is the most common mesenteric intravascular catastrophe. There may be a background of chronic mesenteric ischaemia with weight loss, abdominal pain and often negative investigations. The acute occlusion is usually a thrombus on an atheromatous plaque located either at the origin of the SMA or diffusely in the proximal few centimetres of the vessel. The bowel may therefore be affected from within a few centimetres of the duodenojejunal flexure to the splenic flexure, and no proximal superior mesenteric arterial pulsation is palpable. However, the gut is often variably affected in segments because collateral pathways may lead to a distribution of ischaemic changes that only loosely follow the arterial territories. The surgeon must consider if there is enough viable bowel to allow resection and anastomosis without revascularisation, whether revascularisation is indeed an option and thirdly, when are the best times to resect, rejoin and revisit? Some surgeons, who argue that re-laparotomy is mandatory, advocate stapling of the bowel ends to force a second look after 24 hours. This overrides a strong temptation not to return to theatre if the patient shows early improvement.

Emergency revascularisation is difficult but a bypass graft or a thrombectomy combined with angioplasty and/or stents can be attempted.[7] (See also Chapter 7, p. 122.) The choice of option is easier if preoperative imaging includes a CT angiogram. Preoperative CT is now so common that if mesenteric ischaemia is suspected, intravenous contrast imaged in the arterial phase is a simple protocol modification to request.

MESENTERIC VENOUS THROMBOSIS

Mesenteric venous thrombosis may occur secondary to intra-abdominal trauma, sepsis or malignancy, or in association with portal hypertension. It may occur as a primary event in patients with severe dehydration or other acquired thrombophilia states. In the more chronic presentation, the diagnosis may have been established by CT scan with portal phase imaging or ultrasound. Surgery can often then be avoided by treatment with heparin or thrombolysis. Commonly, however, the presentation is more acute, diagnosis is made at laparotomy and venous infarction of the small bowel is already established. The thrombosed veins are visible and arterial pulsation in the mesentery may still be present. Resection of infarcted bowel is essential, and thereafter the treatment is with heparin to prevent further propagation of thrombus. As a second-look laparotomy in 24 hours to check if there has been no extension of thrombosis is recommended, the resected bowel ends can be closed with staples and any anastomosis delayed.

Postoperative considerations

For any mesenteric catastrophe an extensive resection of small bowel, often with the additional removal of the right colon, may be necessary. An anastomosis can be performed, but the resultant profuse diarrhoea may make the early postoperative period unmanageable. An alternative is to bring out the proximal end as a jejunostomy. This stoma will be of high output and absorption from the colon will be lost until the bowel is re-joined, but the fluid and electrolyte losses can be measured and the perineal skin spared. The long-term problems of intestinal failure are discussed in Chapter 12, but they may prove insurmountable in a frail elderly patient; simple closure of the abdomen without any resection is sometimes the kinder option.

Ischaemic colitis

LEFT-SIDED ISCHAEMIC COLITIS

This condition is common, but fortunately it is usually focal and seldom progresses to full-thickness infarction. Classically, the patient has left-sided abdominal pain followed by bloody diarrhoea. It occurs most often around the splenic flexure or in the descending colon, and the classical X-ray appearance of 'thumb-printing' from mucosal oedema may be present. Left-sided colitis can occur spontaneously against a background of atherosclerosis, and a variant is also seen after aortic surgery, when the inferior mesenteric artery has been ligated. The perfusion of the sigmoid colon may then be inadequate, as it becomes dependent on the marginal artery around the splenic flexure (see Figure 22.2, p. 378).

Mucosal ischaemia, and even mucosal infarction, can be treated conservatively and surgery can often be avoided. However, if there is evidence of full-thickness bowel wall infarction, a laparotomy is unavoidable and non-viable distal colon must be resected. A left-sided colonic anastomosis with marginally ischaemic bowel must be avoided, and a Hartmann's procedure is preferred. The proximal end is brought out as an end colostomy. The distal resection will probably have to be at the level of the peritoneal reflection to ensure adequate perfusion, and should be marked with a long, non-absorbable suture to ease identification at a subsequent operation to restore continuity.

RIGHT-SIDED ISCHAEMIC COLITIS

This is most often encountered in patients who have a serious underlying medical pathology, and is associated with a high mortality.[8] Any form of vasculitis can produce a locally ischaemic patch of bowel that can progress to ulceration and haemorrhage or infarction and perforation. A more extensive form of right-sided ischaemic colitis is encountered in immunosuppressed patients receiving cytotoxic chemotherapy. Neutropaenia is probably the most important factor in the aetiology. If perforation or infarction occurs, laparotomy becomes unavoidable. Usually, the safest procedure is a right hemicolectomy, but without an ileocolic anastomosis. The distal ileum is brought out as an ileostomy, and the transverse colon as a mucous fistula. This is a safer option in these very ill patients than leaving the distal end as a closed colonic stump within the peritoneal cavity.

SURGERY FOR INFLAMMATORY BOWEL DISEASE

Ideally, patients with inflammatory bowel disease are managed jointly by gastroenterologists and surgeons as the decisions if, and when, to operate can be complex. Recent advances in medical treatment will save some additional patients from surgery, but may result in others having their surgery needlessly delayed or undertaken in a suboptimal immunocompromised state. Inflammatory bowel disease includes ulcerative colitis and Crohn's disease, and an indeterminate variety that shows features of both diseases. It may be best for the surgeon to view any indeterminate disease as Crohn's when considering the surgical options.

Ulcerative colitis

The inflammation in ulcerative colitis is confined to the large bowel, and it is a mucosal disease. The excision of all large bowel mucosa offers a cure, but at a price that is frequently unacceptable in mild disease. Many patients are managed exclusively on medical treatment, but others will require emergency, urgent or elective surgery. The majority of patients requiring surgery for ulcerative colitis are keen to avoid a permanent stoma. Pouch reconstruction surgery provides variable results, but is consistently better in the hands of coloproctologists who have developed a particular interest. Referral to these surgeons is therefore recommended.

URGENT AND EMERGENCY INTERVENTION

Close cooperation between surgeons and gastroenterologists is essential as patients may deteriorate despite intensive medical management. Once colectomy can be predicted as inevitable, delay will merely increase the complications of surgery in patients who are physiologically deteriorating and immunosuppressed by steroids and other agents. Surgery can usually be a planned procedure within a few days of this decision, but occasionally true emergency intervention is necessary. Urgency is increased if toxic dilatation of the colon occurs as the viability of the colon becomes threatened and toxins and bacteria enter the circulation. Colonic perforation will inevitably follow, and occasionally surgery has to be undertaken when perforation has already occurred. A caecal diameter of 10 cm, as measured on an abdominal X-ray, indicates that improvement without surgery is unlikely. A transverse colon diameter of more than 6.5 cm may be a more sensitive measure of toxic dilatation and the need for urgent surgical intervention.

Proctectomy as an emergency is usually unnecessary, increases the magnitude of the procedure and makes future pouch reconstruction more difficult. A total colectomy, with rectal preservation and a terminal ileostomy, is the standard procedure. However, where haemorrhage was the predominant reason for emergency surgery the bleeding is most frequently from the rectum and a total proctocolectomy should then be undertaken as the primary procedure. The anus should be preserved if a future pouch is a possibility.

It is important that any patient with a retained rectum is aware of the long-term risks of rectal cancer. Many are reluctant to have the proctectomy, especially if they are symptom free and are not contemplating a pouch reconstruction. They must be advised of the importance of regular screening of the rectal stump.

ELECTIVE INTERVENTION

Persistent symptomatic disease

Persistent symptomatic disease despite medical management is an indication for proctocolectomy. If the patient is unsuitable for a pouch reconstruction, or does not wish one, a proctocolectomy and end ileostomy can be performed as a single procedure. If a pouch is to be considered, the proctectomy and pouch formation are better postponed until the patient is off steroids and immune suppression and has regained good nutritional status, as the complications of pouch surgery increase if performed in suboptimal conditions. In young women, major pelvic surgery carries a significant risk of subsequent infertility,[9] and the option of further delaying proctectomy and pouch reconstruction until after the patient has completed her family should be discussed.

Occasionally, a subtotal colectomy and ileorectal anastomosis is considered in a patient with apparent rectal sparing. There are anecdotal reports of long-term successes, but it is usually an unsatisfactory solution as the rectum is invariably involved to some degree and often deteriorates rapidly during the months following the ileorectal anastomosis.

Dysplasia

Patients with pancolitis of over 10 to 20 years' duration have a significantly increased risk of cancer. Many are relatively symptom free on minimal maintenance treatment. They are therefore reluctant to consider surgery and prefer regular colonoscopic surveillance with biopsies, only agreeing to colectomy when dysplasia has been demonstrated. The proctocolectomy can be combined with formation of an ileal pouch in this situation.

Total colectomy

Total colectomy operation may be combined with a proctectomy and even a pouch reconstruction. It can be undertaken by open surgery or laparoscopically, although an open operation is really the only safe option when there is toxic dilatation. The ascending, descending and sigmoid colon are elevated on their respective retroperitoneal mesenteries and the resection is a combination of right, transverse and left hemicolectomies, as described in Chapter 22. Total colectomy is an operation for benign disease and the resection does not have to include a radical lymphadenectomy. The mobilisation can therefore be more conservative and need not extend to the mesenteric root. The superior rectal artery may be preserved, as in a sigmoid colectomy for diverticular disease, and this is important if the rectal stump is to be left long to be brought up to the abdominal wall. Ligation of the mesentery can be close to the bowel wall but, as this requires ligation of multiple vessels, it is usually preferable to choose a somewhat more proximal site (see Figure 22.2, p. 378). If the colectomy is for long-standing colitis with dysplasia, the danger of an occult malignancy in the colon must be considered and in this situation a more radical lymphadenectomy, with vascular ligations at the mesenteric root, is advisable.

The omentum can be left *in situ* in a total colectomy for benign disease, but it has been implicated in the frequent adhesion obstructions to which these patients are prone. For this reason, some surgeons prefer to excise the omentum. In an emergency colectomy for severe ulcerative colitis, the colon is friable and will perforate easily, and therefore no attempt should be made to enter the plane between the transverse colon and the greater omentum. The greater omentum is separated instead from the greater curve of the stomach between ligatures, and removed *en bloc* with the colon. Both laparoscopically and in open surgery, heat-bonding devices are a fast convenient way of achieving both this and the division of the large bowel mesentery.

The superior rectal artery is preserved and this enables the rectal stump to be left long. This is advantageous, as an intraperitoneal closed rectal stump with severe disease may perforate, and it is safer to bring it out as a mucous fistula. An alternative is to attach the fascia at the lower end of the midline wound around the closed stump (Figure 23.6) and leave the overlying skin open. If the colectomy was performed laparoscopically, the small suprapubic wound for the delivery of the colon can be used. The skin will heal over rapidly if the stump closure remains secure, avoiding the long-term inconvenience of a mucous fistula. However, if the stump blows, a mucous fistula should form without peritoneal contamination. This technique is often referred to, someone inaccurately, as 'a closed mucous fistula'.

The terminal ileostomy is fashioned as described in Chapter 22.

Proctectomy

When a proctectomy is an extension of a total colectomy, the dissection planes around the mobilised sigmoid colon lead naturally into the plane around the mesorectum. Similar conditions prevail when a long rectal stump has been left under the abdominal wound at an earlier total colectomy. Planes can be more difficult to define when a short rectal stump has been left deep in the pelvis. The operation to excise the rectum for rectal cancer is described in Chapter 22. When pelvic surgery is undertaken for benign disease there is considerable emphasis on preservation of the pelvic autonomic nerves. Many surgeons therefore favour a *close rectal dissection*, as the dissection will be kept well away from the nerves. This consists of excision of the rectum, leaving the mesorectum mainly *in situ*. Additional advantages include a smaller pelvic dead space into which small bowel may prolapse, and a supporting surround of fat for the pouch. Multiple ligations of mesorectal vessels on the rectal wall are required, and access deep in the pelvis becomes progressively more difficult as the mesorectum is still filling the pelvis and tethering the remaining rectum into the hollow of the sacrum. Other surgeons therefore prefer to follow the same precise anatomical plane around the mesorectum that they would use for an anterior resection, carefully identifying and preserving the nerves. During the final dissection, however, they cone in through the distal mesorectum to reduce the risk of injury to the autonomic nerves. The dissection is more anatomically elegant, with less bleeding, and if there should be an unsuspected rectal cancer associated with the colitis, oncological clearance is more likely to have been achieved.

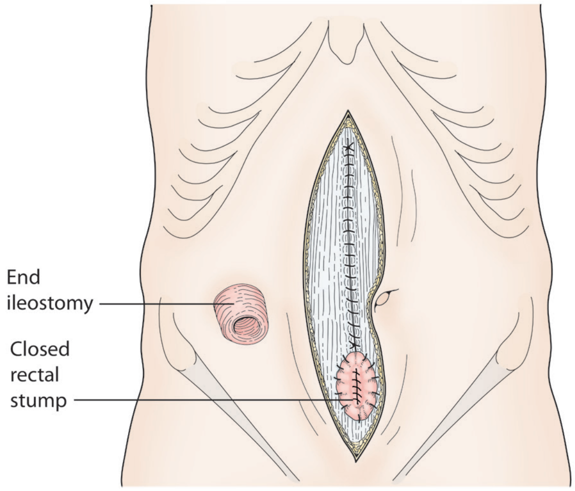

Figure 23.6 *The linea alba of this midline wound has been closed, except for the distal few centimetres, where the edges of the fascia have been sewn around the closed rectal stump. The skin directly over the stump is left open.*

The dissection at the anus varies as to whether a pouch is planned and whether a pouch–anal anastomosis is to be hand-sutured or performed with a circular stapling device. In all situations, however, all columnar epithelium must be excised to eradicate the disease.

If the patient is to have a *permanent ileostomy*, the final dissection is completed from the perineum by dissection in the intersphincteric plane, which is developed from the anal verge and followed proximally to join the pelvic dissection (see Chapter 24). The rectum and anus are removed but, in contrast to the abdominoperineal excision described in Chapter 22, there is no cuff of external sphincter or ischiorectal fat attached to the bowel, and there is no perineal wound.

When a pouch is planned with a *stapled anastomosis to the anus*, the final dissection for the proctectomy is a similar technique to that described in Chapter 22 for a very low anterior resection, but with the modifications already discussed above. It is important that a cuff of columnar epithelium is not left *in situ*, as it may result in persistent inflammation, poor pouch function and a continuing risk of malignant change. Transection of the anal canal, followed by a circular stapled anastomosis, will result in a staple line at the dentate line and the final cuff of transitional mucosa will have been excised as the distal 'doughnut'. The final deep dissection to achieve this is technically difficult, especially in an obese male patient. A close rectal dissection technique may make access even more difficult. In addition, these very low stapled anastomoses are associated with inevitable excision of the proximal part of the internal sphincter (see Chapter 24), which may prove crucial for the passive continence of the semi-liquid pouch effluent. For both these reasons some surgeons prefer a mucosectomy followed by a sutured pouch–anal anastomosis.

When a pouch is planned with a *hand-sutured anastomosis to the anus,* the rectum is divided several centimetres above the dentate line. The anorectal stump is retained, but is then denuded of all columnar epithelium (mucosectomy). The surgeon, working from the perineum, inserts an anal retractor and injects 1:200,000 adrenaline submucosally to lift the mucosa off the muscle wall. The mucosa is then excised from just above the dentate line up to the rectal division. In severe colitis the mucosa is friable and haemorrhagic and will have to be excised in strips. It is very important not to leave any mucosa behind and to obtain complete haemostasis.

Ileal pouch

The terminal loop of ileum is inspected for suitability and, in particular, the apex of the loop must be able to reach to the anus without tension.[10] In a laparoscopic proctectomy this must be checked before the small incision is made to deliver the specimen and bring the terminal ileum outside the abdomen to create the pouch. A **J**-pouch, formed by folding back the terminal ileum on itself, is the simplest. An anastomosis is formed between the two limbs of the loop, each of which should be between 15 and 20 cm in length. Thus, 30–40 cm of terminal ileum is needed for the pouch. The pouch can be constructed very simply with a mechanical stapling device introduced through a small enterotomy at the apex of the loop (Figure 23.7a). Stay sutures to support the ileum are helpful, and a finger swept between the blades of the stapler, before it is closed, rotates the mesentery out of the staple line. A second or third firing of the GIA™ 80 stapler is necessary (Figure 23.7b). Some surgeons prefer a hand-sewn pouch, although there appears to be little advantage and it is more time-consuming. A variety of different pouches have been tried and hand-sutured **W**- and **S**-pouches were briefly popular, but have been largely abandoned as their functioning was inferior. The **S**-pouch in particular was associated with evacuatory difficulties.

Stapled ileal pouch–anal anastomoses

These are performed in a similar fashion to the coloanal anastomosis described in the section on anterior resection of the rectum in Chapter 22.

Hand-sutured ileal pouch–anal anastomoses

These are fashioned per anally, after a mucosectomy, as described above. The orientation of the pouch is decided from the abdomen, and any rotation of the afferent ileum must be avoided. A suture is then passed through the distal opening of the pouch at the 3 o'clock position and the needle passed down through the anus to the perineal operator. This procedure is then repeated at the 9 o'clock position. The pouch is now guided down into the pelvis, and the surgeon passes the needles through the anal mucosa at the lower edge of the mucosectomy in the 3 and 9 o'clock positions. As these two sutures are ligated, the pouch is fixed to the anus in the correct orientation and lies within the internal and external sphincters. A small bite of internal sphincter should be included to avoid the suture tearing through the mucosa. The perineal operator then hand sews the whole circumference of the pouch opening to the dentate line, using fine interrupted absorbable sutures. Access for per-anal surgery is always limited, and care must be exercised in anal retraction as excessive dilation will stretch or disrupt the sphincters.

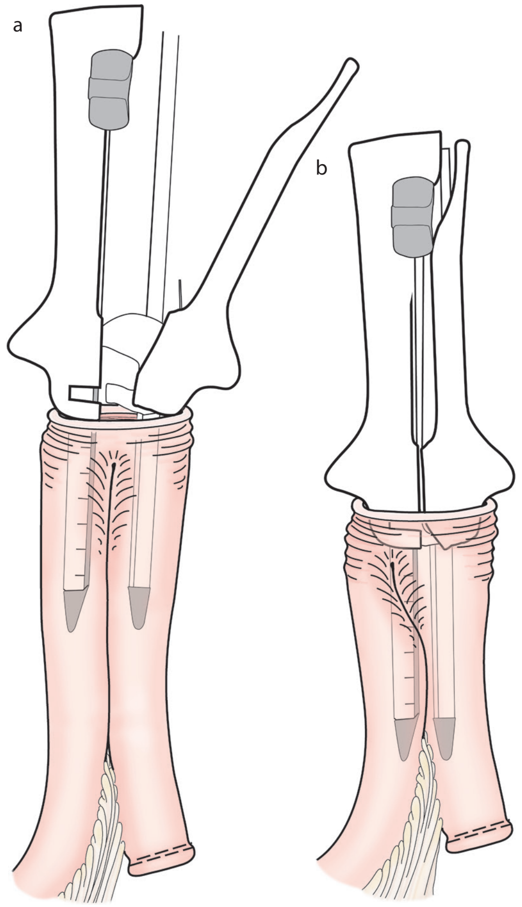

Figure 23.7 *Formation of an ileal pouch. (a) The blades of the stapler are introduced through an enterotomy at the apex of the ileal loop. One blade is inserted into each limb of the bowel, the two blades are locked together, the mesentery is rotated out of the line of the staples and the device closed and fired. (b) The stapler is re-loaded, introduced into the pouch and then on into the remaining separate limbs. A second or third firing completes the pouch.*

Surgery for pouch complications

Ileoanal pouches are not trouble free, and by 10 years about 20 per cent have either been removed or have been defunctioned. Revision pouch surgery is often disappointing, but better results are obtained by referral to surgeons with a special interest in this work. A pouch may have to be revised if there are repeated episodes of inlet or outlet obstruction, or surgery may be undertaken for fistulous complications.[11] Outlet obstruction can be treated by a pouch advancement from below, but any more major pouch revision will require a pelvic dissection from above. The development of a fistula often means that the pouch is doomed. Some fistulae occur during the immediate postoperative period in association with pelvic sepsis, but others occur years later in an otherwise trouble-free pouch and are an almost inevitable eventual complication if a pouch is constructed for Crohn's disease or an indeterminate colitis. A fistula into the bladder or other intra-abdominal organ is repaired from above, and this is also the approach for the extrasphincteric fistula to the perineum. The more common intersphincteric and transsphincteric fistulae are also difficult to treat when associated with a pouch. Scarring from previous surgery makes any flap advancement technique less attractive, and the already precarious continence in these patients may be lost by any sphincter sacrifice. A drainage seton may be the most prudent procedure, but a repair may have to be attempted for a symptomatic pouch–vaginal fistula (see Chapter 24). Often, the pouch must be defunctioned again with a loop ileostomy while further attempts at pouch salvage are pursued. The original histology should be reviewed and if there were any features of Crohn's disease, further efforts to save the pouch will most likely prove futile.

A pouch may have to be excised for poor function, fistulous complications or intractable pouchitis. The latter is more common in pouches created for inflammatory bowel disease than in those for polyposis. The excision of a pouch is along similar lines to a proctectomy, but planes may be difficult to follow. If a replacement pouch has to be fashioned, a further 30–50 cm of small bowel has to be sacrificed. Occasionally, this will be contraindicated if it will leave inadequate small bowel length for absorption.

Crohn's disease

In contrast to ulcerative colitis, Crohn's disease can affect the gastrointestinal tract from the mouth to the anus, and therefore surgery can never guarantee its eradication. However, in patients with localised pathology, excision of all symptomatic disease may provide long-term benefits. The involvement is classically patchy, with segments of inflamed bowel separated by lengths of normal bowel. The inflammation is transmural and, in addition to the mucosal ulceration and haemorrhage that are also seen in ulcerative colitis, deeper oedema or scarring can obstruct the bowel lumen. The inflamed serosal surface of an involved segment may also adhere to an adjacent organ, with subsequent fistulation.

COLONIC CROHN'S DISEASE

This condition may present with very similar features to those of ulcerative colitis and again surgery may have to be considered in both the emergency and the elective settings when medical management fails. The long-term cancer risk is similar to that in long-standing ulcerative colitis and colonoscopic surveillance can be hampered by a more distal Crohn's colonic structure. Total proctocolectomy with a terminal ileostomy is the preferred option if the rectum or anus is also involved. A colectomy and ileorectal anastomosis may be a satisfactory alternative in Crohn's colitis with rectal sparing. An ileoanal pouch carries an unacceptable risk of fistulous complications and should, in general, be avoided.

A defunctioning loop ileostomy can be an excellent temporary measure in severe Crohn's colitis. Intensive medical treatment is continued and if remission is achieved, the ileostomy can be closed. In practice this is seldom recommended as relapse is almost inevitable, but the patient has the opportunity to experience life with a temporary stoma before making a final decision regarding proctocolectomy.

TERMINAL ILEAL CROHN'S DISEASE

This is the most common form of the disease, and resection by a limited right hemicolectomy may be preferable to long-term medical management with steroids and immunosuppression. This is particularly the situation in the adolescent in whom growth and development into adult life are stunted by postponing what is often inevitable surgery. There may be no evidence of other areas of gastrointestinal Crohn's disease and 60 per cent of patients will have no further trouble. Even those who do develop further active disease may have several symptom-free years. Cessation of smoking and continuation of treatment with mesalazine reduce the incidence of further problems, but there is now some evidence that surgical technique may also be important (see below).

Terminal ileal Crohn's disease co-existent with appendicitis is occasionally a difficult operative dilemma. An inflamed appendix with a normal caecum can be treated with a simple appendicectomy, whereas an inflamed appendix secondary to Crohn's inflammation of the caecal pole will require a right hemicolectomy. More difficult to assess is the non-inflamed appendix and the surprise finding of a thickened inflamed terminal ileum, which although probably Crohn's disease, could be a *Yersinia* ileitis or a lymphoma. The presence of 'fat wrapping' supports a clinical diagnosis of Crohn's disease, as it is not a feature of lymphoma or the acute ileitis of *Yersinia*.

A right hemicolectomy for terminal ileal Crohn's disease is a more limited resection than that for a caecal cancer, as described in Chapter 22, because no lymphadenectomy is necessary. However, any loops of small bowel adherent to the inflammatory mass must also be excised. The terminal ileal involvement normally ends at the ileocaecal valve, and the aim of surgery is to remove only the diseased segment, as recurrence proximal to the anastomosis is not prevented by a more radical excision of normal adjacent ileum. The method of anastomosis does, however, appear to influence recurrent disease, and a wide side-to-side stapled anastomosis may be preferable to the traditional sutured end-to-end anastomosis. It is uncertain whether the benefit is related to the width of the anastomosis and the avoidance of any hold-up or whether staples are less irritant than sutures. Certainly, any sutured anastomosis in Crohn's disease should be created with absorbable sutures, and silk in particular is best avoided.

CROHN'S OBSTRUCTION

Crohn's obstruction may result from inflammatory oedema during an acute exacerbation. Clinical decisions are not easy, as the full-thickness inflammation inevitably produces localised signs of peritonism and the exclusion of a strangulated loop is difficult. Surgery can usually be avoided: the obstruction is treated conservatively and the exacerbation of Crohn's inflammation managed with steroids. Chronic fibrous strictures causing partial obstruction of either the small or large bowel are better managed by limited resection or by stricturoplasty. Endoscopic dilatation of these strictures is now another option. A stricturoplasty is carried out by incising the antimesenteric border of the small bowel longitudinally across the stricture and then closing the resulting defect transversely. This has the advantage of preserving the full length of small bowel, and recurrent Crohn's obstruction at a stricturoplasty site is less frequent than at a small bowel anastomosis. Where a diseased segment is too long for stricturoplasty, a small bowel resection should be carried out, but consideration must be given both to preservation of adequate lengths of small bowel (see Chapter 12) and to the inadvisability of performing an anastomosis with diseased bowel. However, it should be remembered that malabsorption can be due to colonisation of partially obstructed small bowel as well as to an inadequate length of residual small bowel.

CROHN'S FISTULAE

Crohn's fistulae may occur into another loop of bowel or into the bladder or to the skin. Treatment is by resection of the fistula and repair through healthy tissue, if possible. Diversion of faecal contents may sometimes be the only practical surgical option.

CROHN'S DISEASE OF THE ANUS

This condition is discussed in Chapter 24.

SURGERY FOR INTESTINAL INFECTIONS AND INFESTATIONS

Treatment of all these conditions is medical, and surgery is only indicated for complications such as haemorrhage, obstruction or perforation. Often, however, the diagnosis has not been suspected preoperatively. Frequently, an ischaemic loop of bowel has been suspected, but at operation the peritonism is found to be from the inflammatory process involving the peritoneum. No surgical intervention is indicated if there is no bowel loop, the integrity of which is in danger. The abdomen is closed and appropriate medical treatment commenced. When there is no firm diagnosis the patient is in danger of inappropriately radical surgery. This may be inevitable, especially if malignancy is suspected, but the surgeon must always consider the possibility of infective pathology. On other occasions, there may be a preoperative diagnosis, but a complication of the infection requires surgical intervention.

Ascariasis (roundworms)

Ascaris lumbricoides obstruction was discussed earlier in this chapter (see p. 414).

Tuberculosis

Abdominal tuberculosis is a common cause of obstruction in endemic areas,[12] either from a 'plastic peritonitis' or a mass of tuberculous glands to which bowel is adherent. A side-to-side bypass is often the most appropriate operative solution. Other presentations include abdominal pain and ascites and small bowel perforations.[13]

Amoebiasis

Infection with *Entamoeba haemolytica* can cause a toxic dilatation similar to that seen in ulcerative colitis. It can also produce a local inflammatory mass, or *amoeboma*, in the caecum and this can mimic a caecal malignancy. If a diagnosis of amoebiasis has been made, surgical resection is only indicated for a complication such as obstruction, perforation or toxic dilatation. These complications should be avoidable, unless the diagnosis and appropriate medical treatment have been delayed.

Typhoid

Typhoid ulcers form over the affected small bowel lymphatic tissue (Peyer's patches) during the third week of untreated typhoid fever. Intraluminal haemorrhage, a walled-off perforation with an associated intraperitoneal abscess and free perforation with generalised peritonitis may all occur. Late presentation and the poor general health of these patients partly account for the high mortality.[14] Some surgeons advocate resection, but simple oversewing is usually adequate.

Cytomegalovirus infection

Infection with this organism usually occurs in immunocompromised patients and may produce an acute inflammatory lesion, which can bleed, perforate or obstruct. The commonest site is in the descending colon, just below the splenic flexure. Treatment is medical, unless a surgical complication ensues.

Pigbel

Pigbel is a necrotising jejunitis, the underlying pathology of which is *Clostridium perfringens*. Treatment of mild cases is with antibiotics and fluid resuscitation but, when more severe, a laparotomy and resection of the necrotic bowel become unavoidable.

Yersinia infection

Yersinia spp. cause an acute terminal ileitis, which may be dif-ficult to differentiate from the terminal ileitis of Crohn's disease. The short history and the absence of the classical fat wrapping of Crohn's disease may alert the surgeon to the correct diagnosis.

SURGERY FOR DIVERTICULAR DISEASE

Small multiple diverticula are a common incidental finding in the sigmoid colon, although they may extend more proximally. Surgery is usually only indicated for patients who develop complications. The symptoms and complications of diverticular disease are almost entirely confined to the sigmoid colon, and only the sigmoid colon need be excised, even when the diverticular process is extensive.

Elective resection

An elective resection may be undertaken for repeated attacks of diverticulitis, for a diverticular stricture or for chronic low-grade symptoms. A *sigmoid colectomy* is the standard operation in the elective setting, and this was described in Chapter 22. In open surgery, a left iliac fossa muscle-cutting incision provides adequate access, but it cannot be extended upwards as easily as a midline incision if more extensive access becomes necessary. The level of the proximal resection is chosen so that the colon reaches easily to the top of the rectum for an anastomosis. It should be above any narrow, thickened sigmoid, but it does not need to be above all diverticula. A division at the level of the proximal sigmoid colon or lower descending colon is usually suitable. The superior rectal artery can be preserved and the sigmoid branches divided, as a radical lymphadenectomy is not necessary for benign disease. The distal resection is at the level where the taeniae have spread to form a continuous muscle coat (Figure 23.8). Division at a more proximal level results in a high incidence of recurrent problems. A hand-sewn anastomosis just below the pelvic brim is often easier than a stapled one, as the instrument may not pass easily up through the folds of the non-mobilised rectum. If the anastomosis is deeper into the pelvis, a stapled anastomosis will be easier.

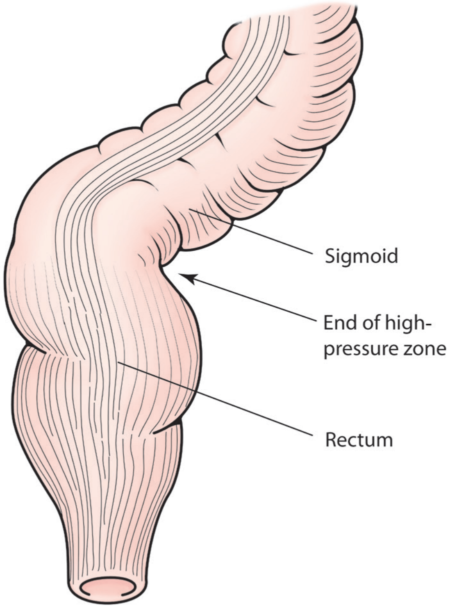

Figure 23.8 *The anastomosis after a sigmoid colectomy for diverticular disease must be to rectum distal to the high-pressure zone of the rectosigmoid junction. The surgical landmark is the spreading of the taeniae to form a continuous longitudinal muscle coat.*

Unfortunately, even in the elective situation this classical sigmoid colectomy may not be possible. A shortened, thickened sigmoid colon and mesentery may make preservation of the superior rectal artery impossible, and the descending colon may not reach for a tension-free anastomosis without full mobilisation of the splenic flexure. Occasionally, the proximal diverticula are so extensive that there is no suitable distal descending colon free of diverticula for a safe anastomosis, and a more proximal level for the transection becomes inevitable. The surgeon must therefore be prepared to carry out a left hemicolectomy rather than a sigmoid colectomy if this is more appropriate.

Many surgeons prefer a left hemicolectomy as their standard procedure for sigmoid diverticular disease. They argue that in addition to avoiding the problems already discussed, it is a more anatomical dissection. Moreover, it is also oncologically sound if an unsuspected cancer is present within the diverticular segment. A more radical removal of diverticula may also improve the long-term outcome of surgery. In addition, straightening of the colon makes any subsequent endoscopic imaging less difficult. Unfortunately, it is also a more major procedure, requires the incision to be extended higher, with a greater risk of postoperative respiratory complications, and splenic flexure mobilisation may result in loss of the spleen as a result of iatrogenic trauma.

The dissection may also have to be carried down into the pelvis if the sigmoid loop is folded over and adherent. Dense adherence to the front of the rectum is best managed by converting the operation into an anterior resection. Dense adhesions to the bladder, uterus or vaginal vault can be pinched off by blunt dissection. If there is a fistulous opening into the dome of the bladder or into the vagina, it is repaired. For both organs dissolvable sutures are mandatory and, as both are very vascular, a continuous haemostatic suture is to be recommended. It is advantageous to position the patient in the 'legs-up' position in anticipation of these problems, as it allows an assistant to retract from between the legs during any pelvic dissection. In addition, the anus is exposed should a stapled anastomosis prove preferable.

URGENT SURGERY

A more urgent operation may be necessary for an attack of acute diverticulitis that fails to resolve on medical treatment. Occasionally, surgery can be deferred if image-guided drainage of a pericolic abscess can be performed, after which the antibiotics are effective in treating the remaining infection. Surgery also has to be expedited in patients who develop a frank colovaginal fistula or colovesical fistula. The operative conditions are worse during an active episode of inflammation than in the elective situation. The bowel is often partially obstructed and there is more likely to be doubt as to whether the underlying pathology is cancer or diverticular disease. The tissues are inflamed, friable and a pericolic abscess is common. The resection is similar to the elective case, but it may be technically more difficult. An anastomosis to restore continuity can usually be recommended, but consideration should be given to the advisability of protecting the anastomosis with a temporary proximal loop stoma.

EMERGENCY SURGERY

Emergency surgery will be necessary if there is generalised purulent peritonitis from rupture of a pericolic abscess or a faeculent peritonitis from rupture of the inflamed sigmoid colon. Less commonly, emergency surgery is necessary for a diverticular obstruction or haemorrhage, both of which can occur in the absence of an acute inflammatory episode. Surgery of these latter two complications has been discussed earlier in the chapter.

Emergency surgery for perforated diverticular disease carries a high mortality. Despite the poor condition of many of these patients when they come to surgery, a resection should be performed as simple drainage, combined with a defunctioning proximal stoma, has generally been shown to be associated with a worse outcome. Unless there is gross faecal soiling of the peritoneum or the patient is so unwell that the operation cannot be safely prolonged, an anastomosis is recommended. A temporary proximal loop stoma, however, is usually advisable, which can be closed at a relatively minor second operation.

When an anastomosis is contraindicated, a Hartmann's procedure is undertaken. The rectal stump is closed and marked with a nylon suture to make subsequent identification easier, and the proximal bowel end is brought out as an end stoma. Some surgeons recommend dividing the lower end more proximally, so that it can be brought out at the lower end of the wound as a mucous fistula to make the subsequent dissection for a rejoin easier. However, this is seldom a satisfactory solution, even when it is technically possible. A segment of distal sigmoid colon affected by diverticular disease has been retained and must be resected at the subsequent operation before bowel continuity can be restored. In addition, if the inferior mesenteric artery has been ligated, this distal colon brought out as a mucous fistula may be ischaemic.

A relatively mild diverticulitis is occasionally encountered at operation for a suspected appendicitis. The decision whether to proceed to a resection or to close the abdomen, with or without a left iliac fossa drain, and treat conservatively will depend on circumstances. These decisions were discussed in Chapter 15.

Differential diagnosis of sigmoid diverticular disease and sigmoid malignancy

Unfortunately, even at the start of an elective operation, preoperative endoscopy, rectal contrast studies and sophisticated imaging may have failed to elucidate whether the sigmoid pathology is diverticular disease or a cancer. Confirmation of the diagnosis by preoperative endoscopic biopsy is often frustrated by the angulation and fixity of the sigmoid loop. Paediatric scopes and brush biopsy techniques will shed further light in some patients, but these are not always successful. CT and MRI scans provide preoperative evidence of the 'invasion' of other organs, but they cannot always differentiate between tumour invasion and the inflammatory involvement of adjacent tissue. If doubt remains after the abdomen is opened, and a sigmoid mass adherent to other organs is encountered, the surgery must be radical to prevent rupture into tumour planes. This requires not only a radical lymphadenectomy but also excision of the adherent disc of any other organ into which invasion is suspected. When this can only be achieved by an extended radical dissection, it is immediately apparent how important it was to have made every effort to differentiate between the two pathologies preoperatively.

Solitary giant diverticulum

A solitary giant diverticulum may occur anywhere throughout the colon, and excision is usually indicated. A caecal diverticulum with an inflammatory mass around it can mimic a caecal carcinoma. However, difficulties in differentiating a caecal inflammatory mass from a caecal malignancy are less common than the diagnostic difficulties in the sigmoid colon.

SURGERY FOR BOWEL CANCER

The principles of intra-abdominal cancer surgery are discussed in Chapter 16 and the standard radical large bowel resections are described in Chapter 22. However, management choices are not always straightforward. Increasingly, the options are considered within a multidisciplinary setting in the light of preoperative staging of both local and metastatic disease. Sometimes, more radical surgery may be appropriate for a locally invasive tumour and can be planned in conjunction with the relevant specialist. For example, a right hemicolectomy can be combined with an *en-bloc* pancreaticoduodenectomy[15] or an anterior resection combined with excision of the bladder (see below). Preoperative local staging, though, has its greatest relevance in rectal cancer where even a T3, N0 tumour can threaten the planes of excision (Figure 23.9). Neoadjuvant (preoperative) radiotherapy, chemotherapy and chemoradiotherapy all have a role in the treatment of rectal cancer and their selective use improves results.

A short (5-day) course of a total of 25 Gy radiotherapy immediately preoperatively can 'sterilise' the tumour periphery and reduce the incidence of pelvic recurrence. At operation the size of the tumour is unchanged and, provided the surgery is carried out without delay, the planes of dissection show no evidence of the treatment. However, late

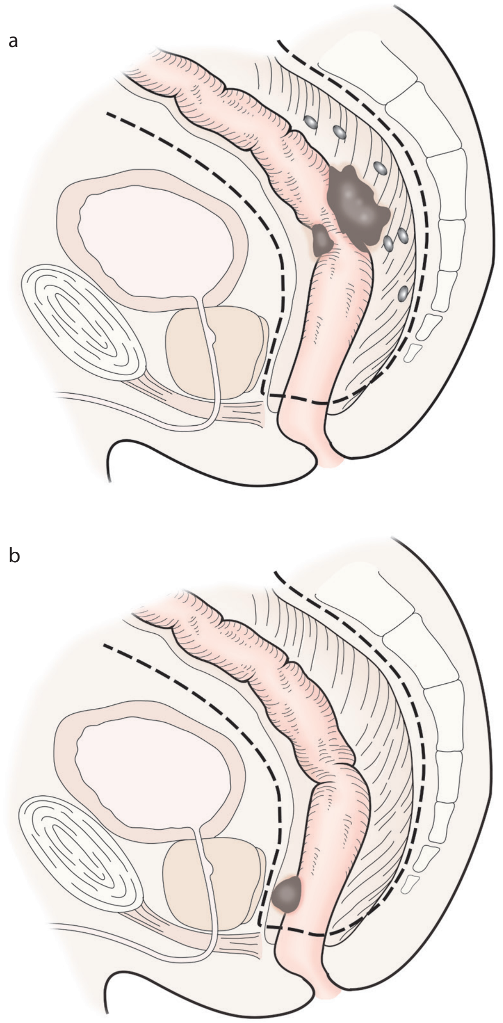

Figure 23.9 *Staging of rectal cancer by MRI scanning is valuable for showing the relationship of the tumour to the planes for excision. (a) A large tumour, which is invading for several centimetres into the posterior mesorectum. There are enlarged nodes, which probably contain metastases. (b) A smaller, earlier tumour that extends only a few millimetres into the thin anterior mesorectum. There is no evidence of nodal involvement. Despite the more advanced staging of the tumour in (a) compared with the tumour in (b), the excision margin, shown as a dotted line, is well clear of tumour in (a) but very close in (b).*

radiotherapy morbidity is at least equivalent to that after the standard long-course regime. Many surgeons therefore only advocate its use selectively for patients at higher risk of local recurrence.[16]

A long course of 45–50 Gy over 6 weeks will shrink and 'downstage' an advanced tumour and thus makes many fixed tumours resectable. Increasingly, this is combined with neoadjuvant chemotherapy. A further delay of 8 weeks after completion of the radiotherapy allows for maximum shrinkage of the tumour. Radiotherapy also kills the cells at the periphery of the remaining tumour mass, and reduces the likelihood of implantation of viable tumour cells in the event of the dissection entering a 'tumour plane'. The surgeon will be aware during the dissection that the planes are more difficult to follow due to radiotherapy changes, and there can also be difficulty in deciding what margins of resection are needed, especially if the tumour has regressed substantially. Both radiotherapy and chemotherapy have the potential to increase the risk of anastomotic leakage after an anterior resection. Both also impair perineal healing after an abdominoperineal resection to the extent that a myocutaneous flap reconstruction should always be considered.[17]

When surgery is delayed for neoadjuvant treatment, a defunctioning stoma is often beneficial, as local symptoms may intensify during treatment. This can be combined with a 'fold-down' technique to prevent loops of small bowel migrating into the pelvis and into the field of radiation. The sigmoid is divided so that the proximal sigmoid is brought out as a terminal colostomy and the distal sigmoid is closed. The distal bowel is then allowed to fold back into the pelvis over the tumour and secured in this position with sutures. Some division of the sigmoid mesentery will be required before the distal end will fold into the pelvis. Great care must be taken not to traverse the lymphatic drainage of the tumour during this manoeuvre. Tissue diagnosis is essential before radiotherapy and, if this has not been successfully obtained preoperatively, Tru-cut® biopsies can be taken from the depths of the mass *transluminally* from above after division of the bowel.

Some of the most difficult management decisions in colorectal cancer revolve around patients with very locally advanced rectal tumours, those with superficial cancers and those with unstable colonic mucosa.

Locally advanced rectal cancer

Symptoms from an advancing, locally invasive pelvic malignancy, whether a primary tumour or a recurrence after surgery, can be difficult to control, especially in patients who are not terminally ill from metastatic disease. There are a few patients with primary or recurrent malignancy confined to the pelvis who should be considered for pelvic exenteration, but for most patients it is not an option. Radiotherapy has an important palliative role. An end colostomy will divert the faecal stream away from a malignant fistula into the bladder or vagina, but a loop colostomy is required if there is also obstruction, or the closed rectal stump may 'blow'. Intraluminal stents can be considered for tumours above the mid rectum, but low stents merely increase local symptoms. Endoscopic debulking may decrease the discharge of blood and mucus and reduce tenesmus. Ureteric and venous stents can be considered for obstructed ureters or iliac veins, but the goals of palliation must not be forgotten with needless intervention, and pain from nerve invasion must be aggressively managed.

It is the avoidance of this scenario that sometimes makes excision of a resectable primary rectal tumour, associated with a small but unresectable metastatic load, an option that should be considered in a fit patient.

PELVIC EXENTERATION AND SACRECTOMY

This radical and mutilating surgery should only be considered if all tumour can be excised. Anteriorly, the excision can include the bladder and prostate or, in a woman, the vagina, uterus and bladder. An end colostomy and urinary diversion, most commonly with an ileal conduit, will then be required (see Chapter 26). Posterolaterally, the excision plane can be outside the autonomic nerves, which are intentionally sacrificed. In selected patients with posterior bony invasion, a sacrectomy can be considered. This surgery should be performed only at centres with special expertise or the results will be disappointing. A portion of the sacrum is excised with the specimen. Excision above S3 destabilises the pelvic ring, but this is occasionally justified. The sacrectomy, and mobilisation of the tumour from below to remove it *en bloc* with the sacrum, is performed with the patient in a prone jack-knife position. Abdominal access is required for mobilisation from above and for the urinary diversion. Either the patient must be turned during surgery or the procedure performed as two separate operations, with the abdominal phase being undertaken the day before the final excision of the tumour through the perineum.[18]

Local excision of superficial cancer

A small cancer confined to the mucosa and submucosa (T1) can often be easily removed by a local excision. This may already have been done at the stage when the cancer was identified histologically in a polyp snared at colonoscopy or when a villous lesion excised per anum was shown to contain an early invasive malignancy. Malignant invasion of the submucosa, either beneath a flat lesion or beneath the stalk of a polyp, carries a risk of lymph node metastases of 5–10 per cent. T1 lesions that are poorly differentiated or invade deeply into the submucosa (Japanese Sm 3) carry a higher risk of node involvement than Sm I well-differentiated tumours. MRI scans may identify nodes, but enlarged nodes may be reactive and normal small nodes may have microscopic deposits. Whether or not to recommend a major resection is a difficult decision and one in which the patient must be involved. Age and fitness are important considerations, as the potential benefit of a more extensive resection must be balanced against operative mortality and morbidity.

On other occasions a decision is taken to excise a superficial rectal cancer *per anum* as a planned procedure. The same reservations regarding possible lymph node metastases remain unresolved. Endoluminal ultrasound and MRI scans are useful in this setting for estimating the depth of invasion, but they tend to overstage tumours and their accuracy in detection or exclusion of small nodal metastases is poor. Deeper T2 and even T3 lesions may also be fully excised locally from below. The risk of involved nodes is higher, but a local excision is justified in patients in whom the risk of death from major surgery outweighs the risk of recurrence from undetected nodal deposits. Perineal and transanal operations, both conventional and with the *transanal endoscopic microsurgical* (TEMS) technique, are considered in more detail in Chapter 24.

Unstable mucosa

ULCERATIVE COLITIS

Patients with ulcerative colitis who develop a cancer should usually be considered for a total proctocolectomy, which includes a radical lymphadenectomy of the segment of mesentery draining the tumour. Cancers in this condition arise more frequently from flat areas of dysplastic mucosa, and regular surveillance cannot be relied on to identify and remove further pre-cancerous lesions. The surgeon, however, will wish to avoid advising needless radical surgery, the difficulties of a permanent stoma or the uncertainties of a pouch when there are fears that a patient may have a limited life expectancy from a relatively advanced index tumour. A decision may therefore be made to limit the initial surgery to treatment of the malignancy and to accept that if the patient remains free of recurrence, a second operation will then have to be considered.

FAMILIAL ADENOMATOUS POLYPOSIS

Patients with familial adenomatous polyposis (FAP) and other related genetic predispositions to colonic polyps and cancer should be managed according to the protocols of the specialist centres, if referral to such a centre for surveillance and surgery is impractical. Patients with FAP are also at risk of upper gastrointestinal polyps and malignancies and intra-abdominal desmoid tumours. The polyps in patients with FAP are too numerous for their total endoscopic removal to be a practical long-term solution. The polyps usually become apparent around puberty, and at this stage a total colectomy and ileorectal anastomosis is the best compromise in these asymptomatic patients who are understandably reluctant to accept a proctectomy. Additionally, postponement of proctectomy and pouch construction in young girls will preserve optimum fertility.[9] Regular surveillance of the rectum and removal of all rectal polyps is continued through adolescence and early adult life. A proctectomy, with ileostomy or an ileoanal pouch, should, however, be considered by the fourth or fifth decade of life, as even with regular surveillance almost 30 per cent will develop rectal cancer by the age of 60 years.

SPORADIC SYNCHRONOUS AND METACHRONOUS TUMOURS

Each tumour should be treated on its merits, receiving a radical excision. Most surgeons are prepared to leave the remaining colon *in situ* in the absence of underlying colitis or FAP, but regular colonoscopic surveillance is imperative. However, a total colectomy and ileorectal anastomosis, or even a total proctocolectomy, should at least be considered in younger patients.

POSTOPERATIVE ANASTOMOTIC LEAKS AND FISTULAE

The management of leaks depends on whether they are early or late, whether they are from large or small bowel and whether there is generalised peritoneal soiling, a localised collection or fistulation.

GENERALISED PERITONITIS

An anastomotic leak that presents as a generalised peritonitis will require reoperation. The peritoneal cavity is cleared of small bowel contents or faeculent material. A simple repair of a defect is seldom practical as the tissues are friable and oedematous. Gastric and duodenal anastomotic leaks may sometimes be managed by oversewing of the defect and diversional bypass. Other solutions include a more radical resection and reanastomosis or the use of a Roux loop brought up as the drainage conduit of an internal fistula. In an ileal or ileocolic anastomosis the safest management is to bring out an ileostomy with the proximal end. The distal end can be closed or brought out as a mucous fistula adjacent to the ileostomy. The latter is safer and also makes the subsequent operation to restore intestinal continuity simpler. A leaking jejunal anastomosis is not so suitable for this management as the stoma will have a very high output. The situation may be better managed by resection and reanastomosis. In colonic leaks, if the anastomosis is above the peritoneal reflection, the safest manoeuvre may be to detach the anastomosis fully and bring out the proximal end as an end stoma. The distal end is safest if brought out as a mucous fistula, and if this is adjacent to the proximal stoma, subsequent surgery to restore gastrointestinal continuity is less complex. Unfortunately, the distal end often has insufficient mobility to make this possible and instead it must be closed and returned to the peritoneal cavity. It is safer to wash out a closed colonic stump that is to be left *in situ*.

PELVIC PERITONITIS

Pelvic peritonitis after a leak from the anastomosis following an anterior resection requires intervention, even if the peritonitis is initially confined to the pelvis. Treatment by taking down the anastomosis and forming an end stoma will almost certainly condemn the patient to a permanent colostomy, as any rejoin at a very low level is difficult and function is almost invariably poor. A better alternative is to select an area of the transverse colon that is suitable for a loop colostomy. An incision is made into the colon and a catheter inserted for a wash-out of the distal colon. A proctoscope is inserted and the effluent is drained from the anus; washing is continued until the distal colon is empty. The colotomy is then enlarged to create the defunctioning loop stoma. No further faecal material should then reach the disrupted anastomosis. If the anastomosis is partially intact, healing should occur and it should be possible to close the stoma some months later. A rectal contrast study should be performed before closure to confirm healing of the anastomosis and no residual connection with a pelvic abscess. Unfortunately, the final function is still often impaired.

SEALED LEAKS

A leak may seal and present as a localised intraperitoneal collection with an associated ileus or small bowel obstruction. Conservative management with intravenous fluids and antibiotics will often suffice, but drainage of the collection may become necessary. A localised collection of infected gastrointestinal contents, walled off within the peritoneal cavity, may track into another viscus or to the exterior via the vagina or the surgical wound. When there is still a leak from the anastomosis into the walled-off collection, a fistula will have been established.

WOUND FISTULAE

A wound fistula usually presents initially as a simple wound infection. It then becomes apparent that intestinal contents are draining through the wound. Immediate repair is not advisable and the initial management is maintenance of fluid and electrolyte balance, drainage of infection, maintenance of nutrition and protection of the abdominal skin from intestinal juices. Ultrasound scans will show whether there is an intra-abdominal collection deep to the wound and, if there is, drainage of this should be improved. If defaecation or a more distal stoma effluent continues, there is still continuity of the gastrointestinal tract and the fistula track may close spontaneously if there is no distal obstruction. When the fistula is from the duodenum or jejunum, parenteral feeding is preferable initially if spontaneous resolution seems probable, as this will reduce fistula losses and healing is more likely. There is little advantage in restricting oral intake in cases of colonic faecal fistulae.

A *persistent fistula* will require surgical repair. The dissection of a small bowel fistula and the anastomosis will be relatively straightforward if the fistula has been allowed to mature. A mature small bowel fistula starts to prolapse, similar to an ileostomy spout, as the peritoneal cavity reforms. This will usually require a delay of around 6–12 months, during which time it is important that nutrition is maintained. Unless the fistula is of very high output, enteral feeding is preferable to intravenous feeding during this period. The 'neo-stoma' of a faecal colonic fistula should also be allowed to mature before further surgery is undertaken to restore intestinal continuity (see also Chapter 12).

RECTOVAGINAL FISTULAE

Rectovaginal fistulae may occur after the breakdown of a pelvic anastomosis. If the bowel was not already defunctioned prophylactically, this is now necessary. The fistula is then repaired as discussed in Chapter 24.

NEONATAL BOWEL SURGERY

Neonatal gastrointestinal surgical conditions should always be managed, if at all possible, by a paediatric surgeon working within a paediatric surgical unit. A successful outcome is dependent not only on surgical technique but also on specialist anaesthetic and intensive care. Unfortunately, any general surgeon who is unable to transfer a neonatal patient and is forced by circumstance to operate will be further hampered by inadequate facilities. It is with such a surgeon in mind that the following text is written and, although the ideal operative management is outlined and can be studied further in standard texts,[19] safer compromises in difficult circumstances are also covered briefly.

INCISIONS

Increasingly, minimally-invasive techniques are becoming an option in specialist centres, but an upper abdominal transverse incision provides good access to the whole neonatal abdomen and pelvis, and is described in Chapter 13. The surgery of congenital abdominal wall defects is also discussed in Chapter 13.

SMALL BOWEL ATRESIA

Small bowel atresia presents with neonatal obstruction or, less commonly, with a neonatal perforation and peritonitis. An intrauterine perforation, occurring some days or weeks before birth, is another variant. Anastomosis of the dilated bowel, proximal to the atresia, to the hypoplastic bowel, distal to the atresia, is technically difficult because of discrepancies of size. A useful technique is shown in Figure 23.10. Unfortunately, intestinal atresia may be associated with other failures of mid-gut development, including malrotation and a short small bowel. Babies who have had an intrauterine perforation will have matted loops of small bowel, and the necessity for a prolonged period of intravenous feeding postoperatively should be anticipated.

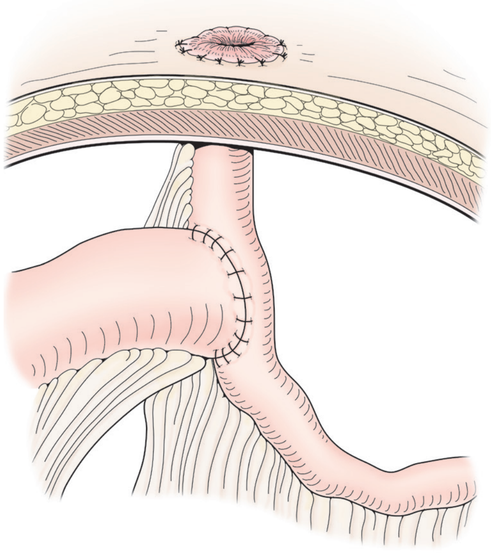

Figure 23.10 *In small bowel atresia, an end-to-side anastomosis of the dilated proximal bowel to the distal hypoplastic bowel can be a useful manoeuvre. In this illustration it has been combined with a temporary end stoma of the distal limb (a Bishop–Koop ileostomy). This stoma can protect the anastomosis if the distal segment is forming a functional obstruction. It can also be used for access to the distal bowel for treatment.*

CYSTIC FIBROSIS

Cystic fibrosis may present in the neonatal period with obstruction from the abnormally viscous meconium and may initially be confused with the obstruction of an atresia. This condition of meconium ileus can initially be managed non-operatively in uncomplicated cases with dilute water-soluble enemata. If surgery becomes necessary, a Bishop–Koop stoma (see Figure 23.10) above the obstructed area allows postoperative mucolytic (acetylcysteine) administration or simple wash-outs to be performed through the stoma.

NECROTISING ENTEROCOLITIS

Necrotising enterocolitis is almost exclusively a disease of the premature neonate. Initial presentation is usually in the second week after birth, with general clinical deterioration and abdominal distension. Intestinal intramural gas, demonstrated on X-ray, confirms the diagnosis. Necrotising enterocolitis is initially a mucosal disease and at this stage conservative management, with cessation of enteral feeding, combined with antibiotics and fluid and electrolyte replacement, may be successful. Systemic complications can include endotoxic shock and disseminated intravascular coagulation, and the baby may require intensive support. The necrotic mucosa may slough and regenerate, but progression to full-thickness necrotic bowel and perforation will require intervention. This may initially be in the form of peritoneal drainage as a temporary measure in an unstable patient, and although some patients may not require further surgery, the majority will need a laparotomy, resection and probable stoma formation. These premature, sick infants are unlikely to survive surgical intervention outside a specialist centre.

ANORECTAL MALFORMATION

Anorectal malformation has historically been classified based on the distal level of the rectal pouch in relation to the levator ani muscle. It is now better classified by the location of the fistulous extension forwards into the urogenital tract or perineum, allowing the spectrum of anomalies to be divided into those best managed initially with a diverting colostomy or those suitable for primary perineal repair. It also provides a more accurate prognosis for each specific anomaly.[20] Even apparently minor anomalies should be managed by surgeons with a special interest, or results will be disappointing.

In newborns without evidence of a perineal fistula, a divided colostomy at the junction of the descending and sigmoid colon, in which two stomas are formed separated by a bridge of skin, is initially undertaken. A loop colostomy, where faecal material can be drawn over into the distal bowel, was thought to increase the risk of urinary infections through the fistula, but this has never been substantiated. In 'high' anorectal malformations the pelvic floor anatomy and physiology are abnormal. Final continence, even after expert surgery, may therefore be disappointing. In these cases the fistulous track in the male is into the bladder neck or proximal urethra (Figure 23.11), and in the female the track fuses with the vagina and urethra to form a single common channel as a persistent cloaca.

Most paediatric surgeons now adopt a posterior sagittal approach to repair anorectal malformations (see Chapter 24, p. 455), but the higher anomalies usually require a concomitant laparotomy. Any fistulous connection is ligated. The rectum is separated from the urogenital tract and mobilised to gain enough length for the bowel to be drawn through the correct anatomical path, anterior to the levator muscle within the limits of the muscle complex and external sphincter. The bowel is then anastomosed to the skin of the perineum at the anal dimple.

The most common anomaly in females is a vestibular fistula (opening into the posterior forchette of the vagina below the hymen) and for this anomaly primary definitive surgery may be advocated if the surgeon has experience in neonatal anorectoplasty; separation of the walls of the rectum and vagina requires meticulous and delicate dissection to avoid injuring either. Any general surgeon who is unable to transfer such a neonate would therefore be better advised to raise a divided colostomy and delay the more major procedure.

Primary posterior anoplasty is best reserved for newborns with cutaneous fistulae in which the rectum opens into a stenotic orifice anterior to the centre of the anal sphincter. This variant may also take the form of a covered anus with meconium visible beneath the thin covering, and in boys an anterior extension is commonly visible as a track of meconium under the median raphe of the scrotum. The appearance of meconium on the perineum may take over 24 hours from birth to develop and therefore any decision to perform a diverting colostomy should be postponed for at least 24 hours. However, no delay is needed if meconium appears in the urine, as this indicates a rectourinary fistula.

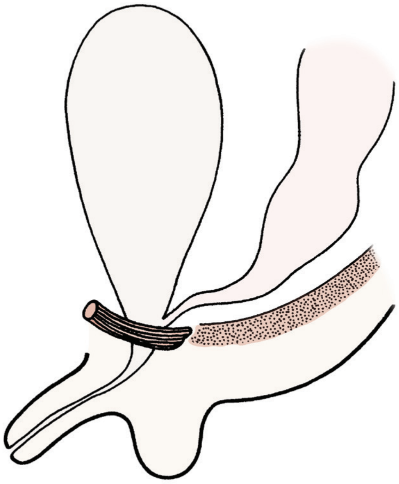

Figure 23.11 *A 'high' anorectal atresia in a male infant. The bowel ends as a fistulous connection into the bladder neck.*

HIRSCHSPRUNG'S DISEASE

Hirschsprung's disease is caused by absence of enteric ganglia in the distal colon resulting in a functional obstruction. The length of the segment of affected bowel is variable, but distally it extends to the anal canal. Commonly, the rectum and sigmoid colon are both involved, but ultra-short segments extending only to the mid rectum, and cases in which the whole colon is affected, are also well recognised. Hirschsprung's disease may present either neonatally or later in infancy or childhood with a large bowel obstruction or intractable constipation. The diagnosis is confirmed histologically by a rectal biopsy in which thickened nerve trunks and absent ganglia are demonstrated in the submucosa.

Paediatric surgeons can now usually manage even those who present neonatally without an initial colostomy. Daily colonic wash-outs are continued until the baby is big enough for a primary pull-through operation. Whatever the length of bowel that is affected, the aganglionic segment must be excised and continuity restored by a coloanal anastomosis. If a stoma is not present, the extent of the aganglionic segment needs to be established with frozen-section histology. When there is already a stoma this will have been made close to the distal extent of the normal bowel. Multiple seromuscular biopsies are taken laparoscopically or at laparotomy. The small size of the neonatal anus makes both the dissection and the coloanal anastomosis difficult, and a variety of techniques have been developed to overcome the difficulties in access. In adult coloproctology the application of these techniques (described below) is limited, but occasionally they have a place in benign disease.

Where specialist paediatric services are unavailable and presentation for treatment often delayed, a general surgeon may be forced to operate on an infant with an advanced large bowel obstruction. The immediate surgical management is the formation of a stoma followed by referral of the child for assessment and definitive surgery. The stoma is formed in the dilated normal bowel, proximal to the non-dilated aganglionic segment that is forming a functional obstruction. A transverse colostomy is therefore usually the most appropriate stoma. Occasionally, the whole colon is aganglionic and an ileostomy will be necessary. In the very sick infant with late presentation, gangrenous enterocolitis may already have occurred in the dilated colon and a subtotal colectomy and terminal ileostomy is then the only surgical option.

Soave's anorectal pull-through

The rectum is mobilised and a circular myotomy made through the mid-rectal wall to enter the submucosal plane. The dissection is then continued in the submucosal plane to the dentate line, where the mucosa is divided. Alternatively, the dissection can be performed transanally, starting circumferentially approximately 5–10 mm above the dentate line to enter the submucosal plane and then continued cranially until the level of the peritoneal reflection is reached.

Normal bowel is then drawn through the denuded rectal muscle tube and the distal aganglionic bowel, with the attached tube of rectal mucosa, is excised. In Hirschsprung's disease the rectal muscle tube must be split longitudinally, posteriorly in the midline down to the internal spincters, to relieve the functional obstruction. A coloanal anastomosis is then performed, although in the original descriptions of this technique a formal anastomosis was not attempted. The colon that had been drawn through the anus was left extruding by several centimetres. It became fixed by adhesions and finally sloughed or was later excised.

Swenson's operation

The rectum is transected and the rectal stump inverted by forceps introduced through the anal canal. Normal colon is drawn through the invaginated rectal stump, and the everted rectum is then excised. The anastomosis, performed just above the dentate line, is completed outside the anus and is then replaced back inside the sphincters.

Duhamel's operation

In this operation, a significant portion of the aganglionic rectum is retained. The upper rectum is divided and closed, the abnormal colon excised and the normal proximal bowel mobilised. A tunnel is then created behind the rectum and this space is entered from the anus by an incision 1 cm above the dentate line. Normal bowel is then drawn through the tunnel, to lie alongside the rectum (Figure 23.12). The distal end of this bowel is then anastomosed to the opening in the upper anal canal. Access for this sutured end-to-side anastomosis is restricted in infancy, but the circular stapling devices that have proved useful in adult patients are too large. A linear cutting stapler is then introduced *per anum* and used to form a side-to-side anastomosis between the native rectum and the normal bowel lying alongside it. Alternatively, if the divided rectum was left open and a colotomy made in the anterior wall of the normal bowel, this side-to-side anastomosis and complete elimination of the dividing wall can be accomplished with a linear stapler introduced from above, before completing the anastomosis with a sutured closure.

Before the availability of stapling devices, this side-to-side anastomosis was achieved with a crushing clamp left *in situ* until the tissue separated and the clamp was passed. The difficulties of the initial sutured end-to-side anastomosis could again be overcome by leaving excess colon to slough.

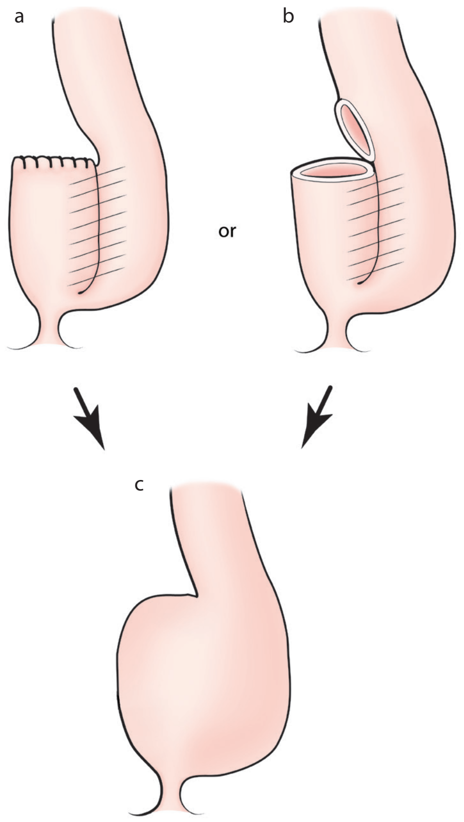

Figure 23.12 *Duhamel's operation. The rectal stump has been closed in (a) and normal bowel anastomosed to it just above the dentate line. The two adjacent bowel walls, which have to be eliminated from below by a linear stapling device, are shown with cross hatching. In (b) the rectal stump has been left open and a colotomy has been made in the normal bowel to allow this side-to-side anastomosis to be performed from above. Both methods result in (c), a neorectum formed by a combination of ganglionic and aganglionic bowel.*

BOWEL SURGERY IN INFANCY AND CHILDHOOD

Surgery in infancy

Hirschsprung's disease and other congenital abnormalities may present after the neonatal period. Intussusception and inguinal herniae are also common. It should be remembered that obstruction in the first year is most often caused by a strangulated inguinal hernia, which is discussed in Chapter 25.

Duplication of a segment of bowel results in a mucus-filled cyst, which slowly expands and causes symptoms by pressure. Excision is indicated.

Malrotation describes the condition in which there is a failure of the normal embryological anticlockwise rotation of the gut. The most common presentation is with obstruction, which may be complete or intermittent and partial. Obstruction may occur for the first time in the neonatal period, in infancy or in later childhood. A simple obstruction in a child, or an individual at any age with malrotation, may occur from a peritoneal band (Ladd's band) compressing the duodenum as it runs across to the superomedially displaced caecum. Alternatively, a volvulus can occur of the abnormally mobile mid-gut, which is suspended on a narrow pedicle of mesentery. At operation, a Ladd's band should be divided. If a volvulus has occurred, counterclockwise reduction followed by resection of non-viable bowel follows general principles. Any attempt at fixation of the mobile mid-gut or correction of the malrotation is seldom of any value. The narrow base of the mesentery is widened by incising the overlying peritoneum. The small bowel is then placed on the right side of the abdomen, with the caecum to the left side to maximally widen the mesentery.

Intussusception is a common cause of obstruction in a previously healthy older infant. The passage of bloody stools or a right hypochondrial mass aids diagnosis. Unless there is strangulation of the bowel, reduction can usually be achieved non-operatively by air or contrast enema under fluoroscopic or ultrasound control. In contrast to an intussusception in an adult, the apex of the intussusception in infancy is almost exclusively a benign lymphadenopathy, and laparotomy is only indicated if reduction is not possible by non-operative means. However, for these techniques to be safe and effective, expertise is essential and transfer to a paediatric centre is indicated if ultrasound has confirmed the clinical diagnosis. Surgical reduction and the indications for resection are described above in the section on intussusception in adults.

Surgery in childhood

Most congenital abnormalities will have presented in infancy, but malrotation, Hirschsprung's disease and duplication cysts may have a late presentation. Inguinal herniae are common, but are less likely to strangulate in later childhood than in infancy. An adult range of pathologies starts to emerge, with appendicitis and inflammatory bowel disease becoming more common. The surgical management of these conditions is similar to that in adults, with only minor variations, and is discussed in the relevant sections.

THE APPENDIX

Appendicitis in childhood is discussed in Chapter 22.

The appendix has found a role as a catheterisable continent stoma. It is removed, with its carefully preserved mesentery, reversed and the base used for the stoma. The tip can then be implanted into the bladder, with invagination or tunnelling to prevent leakage. This Mitrofanoff procedure can avoid the need for permanent catheterisation or urinary diversion in children with spina bifida. Alternatively, if reimplanted into the colon, a Malone antegrade continence enema (MACE) can be instituted in the management of children with faecal incontinence or intractable constipation. Less commonly, the appendix is left *in situ* and the stoma formed with its tip.

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24

SURGERY OF THE ANUS AND PERINEUM

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Many patients present to the surgeon with anal symptoms. All patients require careful assessment to exclude serious pathology. Most, however, will be found to have minor anal pathology, the majority of which will require no surgery. Many patients only require reassurance that the symptoms are not caused by cancer. Others have troublesome symptoms for which medical treatment or a minor procedure undertaken in the outpatient clinic may be all that is required. Many with defaecatory problems or impaired continence will require careful assessment of their problem, but only a minority will be helped by surgery.

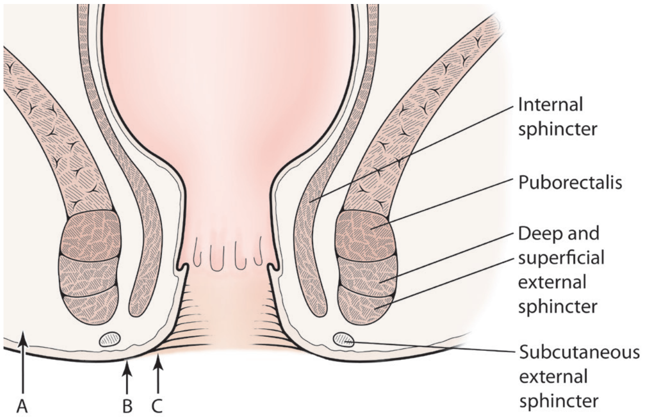
ANATOMY AND PHYSIOLOGY

An understanding of the anatomy and physiology of the anal canal is of major importance to any surgeon undertaking even the most minor anal operation, as stretching of the sphincter muscles or partial division, whether inadvertently or in the treatment of a fissure or fistula, may have a deleterious effect on continence.

Anatomy

The anal canal passes downwards and backwards for around 4 cm as a direct but narrower extension of the rectum to end at the anal orifice, or *anal verge*. The anal verge is taken as the reference point when measuring the height of any rectal or distal colonic lesion. The *internal sphincter* is a condensation of the circular muscle of the bowel wall. When the external sphincter is relaxed, the distal edge of the internal sphincter can be felt at the anal verge (Figure 24.1). However, as the subcutaneous fibres of the external sphincter contract they form a circle of muscle distal to, rather than around, the internal sphincter. The *external sphincter* is a composite striated muscle. Its lower fibres encircle the anal canal and they can be, somewhat arbitrarily, subdivided into deep, superficial and subcutaneous portions. Superiorly, the external sphincter blends with the puborectalis portion of the levator ani muscle of the pelvic floor. The puborectalis muscle sling does not encircle the anus and is deficient anteriorly (Figure 24.2). The circular portion of the external sphincter is shorter in women, particularly anteriorly.

The lining of the anal canal changes at the *dentate line*. Below this line it is modified skin, or anoderm, consisting of squamous epithelium, but above the line the mucosa is a



Internal sphincter
Puborectalis
Deep and superficial external sphincter
Subcutaneous external sphincter
A
B
C

Figure 24.1 *Diagrammatic coronal section of the anal canal. The longitudinal anal folds terminate in the anal valves at the dentate line. The extrasphincteric plane (A) is into the fat of the ischiorectal fossa beneath the levator ani muscles. In the relaxed anus the subcutaneous fibres of the external sphincter lie outside the internal sphincter and the intersphincteric groove (B) is palpable. The submucosal plane (C) is continuous with the subcutaneous plane beneath the anoderm.*

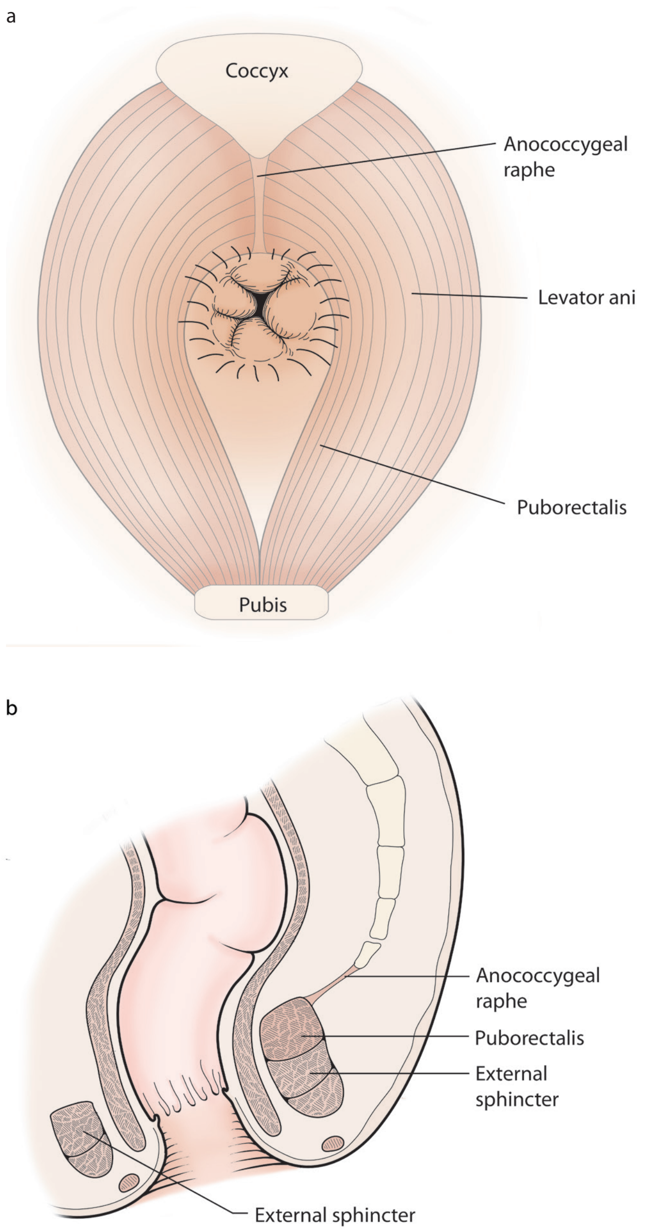


Figure 24.2 *(a) The pelvic floor musculature viewed from below. The puborectalis sling is the anteromedial free edge of the levator ani muscle and is of great importance in continence, although it does not encircle the anus. (b) The diagrammatic sagittal view of the anus demonstrates the absence of puborectalis anteriorly.*

similar columnar epithelium to that of the remainder of the colon and rectum, except that there is a *junctional zone* extending for about 1 cm above the dentate line. This change in the mucosa is important, as malignant lesions arising in the distal anal canal are more likely to be squamous cell carcinomas than adenocarcinomas. The dentate line also marks the watershed for lymphatic drainage. The upper anal canal drains to the inferior mesenteric nodes and the lower anal canal to the inguinal nodes. The dentate line is also the division between somatic and visceral sensation. Distal pathology in the anal canal may thus be extremely painful, whereas pain is a later feature of pathology at the anorectal junction. This is also the reason why it is possible for the surgeon to inject sclerosants or place mucosal bands *above* the dentate line with only minor discomfort. The dentate line can be identified visually, as the mucosa above is loosely attached and hangs in longitudinal folds, which are joined at the dentate line by crescentic folds, or *anal valves* (see Figure 24.1). The *anal glands* lie partly in the submucosal plane and partly between the sphincters in the intersphincteric plane; infection in these glands is thought to be the main cause of perianal sepsis and fistulae. The orifices of the glands open just above the anal valves and this is therefore the commonest site of the internal opening for a fistula (see below).

Vascular plexi lie beneath the mucosa of the anal canal. The main arterial inflow is from the terminal branches of the superior rectal artery, which classically divides into a left lateral, a right anterolateral and a right posterolateral branch; they anastomose with branches of the inferior rectal artery. Three small swellings, or *anal cushions*, are associated with the underlying vascular plexi. A *haemorrhoid* is an excessive distension of a vascular plexus, which stretches the overlying mucosa and anoderm, loosening their attachments to the muscle wall of the anal canal.

Physiology

DEFECATION

Defecation is a complex interaction of reflex sphincter and pelvic floor relaxation associated with a propulsive peristaltic wave. To this is often added voluntary straining to increase intra-abdominal pressure. Straining will overcome difficulties secondary to poor sphincter or pelvic floor relaxation, to an inadequate peristaltic wave or to a disproportionally large stool. However, straining also causes haemorrhoidal swelling, which in itself partially obstructs the passage of stool. Minor defecatory difficulties, often associated with bleeding and prolapse of haemorrhoidal tissue, may result. Some patients, however, develop more severe difficulties and present with a range of symptoms, collectively described as the '*obstructed defecation syndrome*'. These patients complain of incapacitating evacuatory problems often associated with tenesmus. The difficulty is thought, at least in part, to be due to failure of relaxation or even inappropriate contraction of the pelvic floor during defecation. Trauma from straining can cause an ulcer, which is commonly in the lower anterior rectum (solitary rectal ulcer). Intrarectal intussusception and even full-thickness rectal prolapse may also develop. Excessive perineal descent from straining can also stretch and damage the pudendal nerves. Surgery seldom has any place in the treatment of obstructed defecation, and biofeedback has proved to be the most promising line of management.

After rectal resection and the formation of a coloanal or ileal pouch–anal anastomosis, there is inevitably a deficient afferent limb to any defecatory reflex initiated by the presence of faeces above the sphincter. There was initial theoretical concern that evacuatory function would be poor, but this has not proved to be a major problem.

CONTINENCE

Continence is also complex, as it is a balance between the effectiveness of the anal sphincters and the pressures that they have to withstand. Severe dysentery can cause incontinence, even in young men with excellent sphincters. Conversely, some elderly women with little measurable sphincter function may remain 'continent' due to a regular and constipated bowel habit, only to complain of incontinence when they develop some other large bowel pathology. Sphincter pressures naturally decline with age as muscle fibres in the sphincters are replaced with fibrous tissue. This natural deterioration also affects the muscles of the pelvic floor. The ability to detect flatus or faeces in the lower rectum or anal canal, and to differentiate between them, is another factor in the maintenance of continence. Deterioration in anorectal sensation also occurs with advancing age. However, partial sphincter denervation from pudendal nerve neuropathy is less important than was previously believed.

Resting anal pressure

Passive continence is the ability to prevent passive leakage of rectal contents. Leakage can occur without a major propulsive peristaltic wave, and is prevented by an effective anal seal and the resting anal pressure. The haemorrhoidal cushions form a soft seal to the anal canal, but the seal is mainly dependent on the activity of the unstriated muscle of the internal sphincter. Of equal importance is whether the lower rectum has faecal matter within it, and the consistency of that matter. Good passive continence is imperative in preventing leakage of semi-formed ileal pouch contents and, as anal pressures decrease with advancing years, a pouch–anal reconstruction may not be a good solution for an elderly patient. A stapled anastomosis at the dentate line after a total proctocolectomy sacrifices the upper portion of the internal sphincter. For this reason, some surgeons prefer a mucosectomy and a hand-sewn per-anal anastomosis to stapling in order to excise all the affected mucosa while still preserving the whole length of the internal sphincter (see Chapter 23). Blood and mucus in the lower rectum present a similar challenge to continence, and an elderly patient with a rectal cancer or villous adenoma may present with passive incontinence. A patient with a very poor resting anal pressure who suffers from incomplete evacuation on defecation may lose small pellets of solid faeces. This problem will be compounded if anorectal sensation is poor and the patient is unaware of the passage of stool.

Anal squeeze pressure

This is the maximum voluntary pressure that the patient can exert to close the anal canal, and is thus of more importance in delaying a call to stool than in maintaining passive continence. The voluntary increase in pressure is produced mainly by the external sphincter, but it is supplemented by other muscles of the pelvic floor and even by gluteal muscle contraction. These additional muscles of continence may be sufficient to compensate for a severely disrupted external sphincter after childbirth. A young woman may initially maintain acceptable continence, but present with impaired continence years later as other compensatory muscles atrophy with advancing age. The ability to delay defecation is not solely related to sphincter integrity. The strength of the peristaltic waves in infective colitis, diverticular disease or inflammatory bowel disease may challenge even the normal sphincter. An additional factor is the volume and compliance of the rectum or neorectum to accommodate and store additional faecal material.

Anorectal physiology, including its investigation, and the maintenance of continence are complex subjects and further reading on these topics is recommended.[1]

GENERAL TECHNIQUE

Surgical approach

The importance of anal operations is often underestimated and the surgery delegated to relatively inexperienced surgeons. However, unless this surgery is undertaken to a high standard and with attention to detail, there is considerable potential for avoidable iatrogenic damage.

ACCESS

Anal surgery is difficult in the presence of faeces in the rectum. A preoperative enema is usually sufficient to clear the operative field, after which surgery can be performed in either the lithotomy or the prone jack-knife position (Figure 24.3). A proctoscope holds the anus open and allows visualisation of, and access to, the lower rectum. Unilateral anal retraction displays the opposite half of the anal canal, and the curved Sims retractor can be useful for this. However, bivalve retractors, a variety of which are available, usually afford superior access with visualisation of, and surgical access to, the anus between the blades of the retractor. The Lone Star System™ gives excellent self-retaining retraction, with a series of disposable skin hooks that are inserted circumferentially. Each small hook is at the end of a long slim plastic-covered spring, which is then fixed onto the circumference of the ring retractor encircling the anus. Prolonged or excessive anal retraction by any method can damage the internal sphincter, however, and great care must be exercised.

ANAESTHESIA

Adequate anaesthesia, whether general, regional or local infiltrative, is essential for any procedure on the sensitive anoderm below the dentate line. For per-anal surgery on the relatively

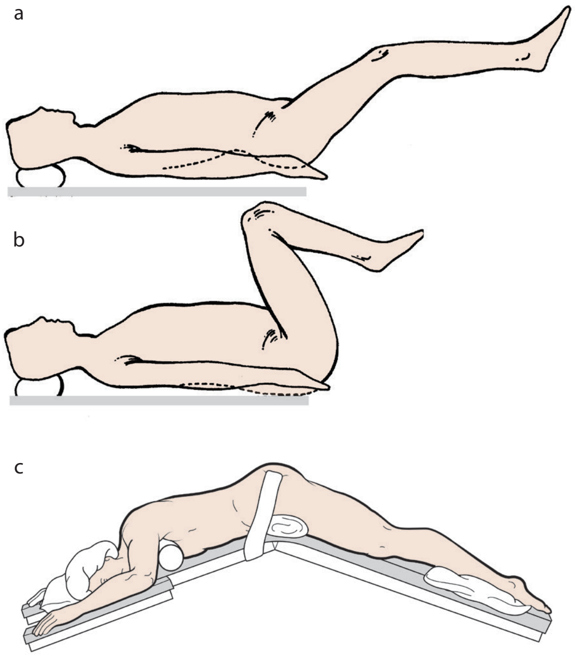


Figure 24.3 *(a) The Lloyd–Davies position is suitable for a lengthy procedure where abdominal and perineal access is required. Perineal access is restricted even when a steep head-down tilt is employed. (b) The lithotomy position is a better position for any anal dissection, but the acute flexion of hips and knees is undesirable for any protracted period. The position of the thighs also restricts any simultaneous pelvic or abdominal access. (c) The prone jack-knife position with the buttocks strapped apart affords excellent access to the posterior perineum and anus with less venous congestion. The disadvantages are mainly in the turning and ventilation of an anaesthetised patient in this position, which makes it an unattractive option for a short minor procedure.*

insensitive rectum, the role in order anaesthesia is predominately to relax the anal sphincters in order to facilitate access.

INITIAL PROCEDURE

Anal operations should commence with a digital rectal examination and proctoscopy. If there is to be any open external wound, the perianal skin should be shaved at the start of the procedure, as hair matted with blood will become adherent postoperatively and greatly increase patient discomfort.

DISSECTION

Precise dissection in anatomical planes and the identification of the sphincters is the key to successful anal surgery (see Figure 24.1). Uncontrolled haemorrhage during dissection obscures vision and must be avoided. Diathermy dissection therefore has considerable advantages. External sphincter fibres twitch when stimulated by diathermy current, and this observation can aid identification during dissection. Injection of a dilute solution of adrenaline (1:400,000) before commencing surgery will reduce haemorrhage and, if injected into the plane to be followed, can make the dissection easier. While some surgeons favour this technique, others find that it distorts the anatomy and is unhelpful. Three different anatomical planes may be followed in anal surgery:

- The *submucosal plane* for a haemorrhoidectomy is entered outside the anal verge; for a mucosectomy it is entered at the dentate line; for a Delorme's procedure it is entered 1– 2 cm above the dentate line; and for a transanal excision of a villous adenoma it is entered close to the base of the tumour.
- The *intersphincteric plane* is the key to anal sepsis and fistulae. It is also the plane through which the rectum can be excised either from above or from below for benign conditions. It is entered from below at the palpable intersphincteric groove at the anal verge.
- The *extrasphincteric plane*, which is entered when draining an ischiorectal abscess, ends blindly at the pelvic floor musculature. This is also the plane for abdominoperineal excision of the rectum (see Chapter 22). A rectocoele can be approached through the extrasphincteric plane between the circumferential portion of the external sphincter and the vaginal mucosa, as there is an anatomical window through the pelvic floor in the midline anteriorly (see Figure 24.2). To enter the extrasphincteric plane from the perineum, the surgeon must be confident of the position of the external sphincter. The perianal skin is more deeply pigmented for a few centimetres outside the anal verge, and the change to normal pigmentation is the surface landmark of the external sphincter.

THE ANAL WOUND

Any bleeding from a raw surface should be stopped by diathermy coagulation. The traditional large anal pack is almost always unnecessary and causes significant postoperative pain. A small absorbable haemostatic pack is favoured by some surgeons, but is expensive. Local infiltration of bupivacaine with adrenaline is effective in arresting minor ooze and will also reduce early postoperative pain. Anal skin wounds are often left open, and a greased dressing will prevent adherence to clothes or pads and reduce discomfort. Absorbable sutures should be used in the anal mucosa and in the anal verge skin.

Faecal contamination of an anal wound seldom gives rise to major local or systemic sepsis.[2] It is even safe to use non-absorbable material for suturing the anal sphincters, although the use of non-absorbable mesh should generally be avoided. Minor infection is, however, probably common, and is believed to be the cause of the increase in postoperative pain at about 3–5 days after a haemorrhoidectomy.[3] The early passage of hard faeces causes pain and even mechanical disruption of a repair. Postoperatively, stool softeners are used routinely to encourage an early soft motion. The addition of a course of preoperative stool softeners will be more effective in achieving this. A temporary stoma should be considered in some circumstances.

Postoperative complications

- *Urinary retention* is common after anal procedures and in more major perineal operations anterior to the anus, prophylactic urethral catheterisation should be considered.
- *Early haemorrhage* after anal surgery is usually best treated by a return to the operating theatre, examination under anaesthesia and coagulation or ligation of the bleeding point.
- *Secondary haemorrhage* at 10–14 days may be profuse. As neither sutures nor diathermy are likely to arrest the bleeding from friable infected granulation tissue, it is initially treated conservatively with blood replacement and antibiotics. A balloon catheter introduced into the rectum, followed by inflation of the balloon for local pressure on the bleeding area, can be an effective manoeuvre.
- *Anal stenosis* and *anal mucosal ectropion* are complications of anal surgery where too much anoderm has been sacrificed; they occur mainly after haemorrhoidal surgery. For many mild forms, conservative management with anal dilators, stool softeners and protection of the perianal skin from minor discharge often suffices. More severe symptoms may justify surgery. A simple **Y-V** advancement flap may help (see Figure 24.7a).

HAEMORRHOIDS

Haemorrhoids are a distension of the normal vascular haemorrhoidal cushions. *Internal haemorrhoids* are submucosal and above the dentate line. Initially, symptoms are confined to bleeding, during or after defecation (1st degree). The lax mucosa, which is separated from the underlying muscle wall by the distended vascular plexus, later prolapses along with the haemorrhoidal tissue during defecation, but reduces spontaneously after defecation (2nd degree). Haemorrhoids that no longer reduce spontaneously (3rd degree) require digital replacement. Failure of replacement may progress to *thrombosed prolapsed internal haemorrhoids*, which are also described as *strangulated piles*, although the strangulating effect of the sphincters is variable.

There is frequently some extension of haemorrhoidal tissue below the dentate line, and the distension of this, combined with prolapsing from above, separates the entire anal canal epithelium from the underlying muscle wall. The anus becomes protuberant, with the external component of the haemorrhoids visible as broad-based tags at the anal verge. These are predominantly skin covered, although there may be mucosa visible on eversion of the tag. Permanently prolapsed haemorrhoids (4th degree) have traumatised exposed mucosa, which produces a mucous discharge.

Many patients with minimally-symptomatic haemorrhoids require no intervention other than exclusion of a rectal neoplasm or other serious pathology. Treatment, to be effective, must either reduce the size and vascularity of the haemorrhoidal cushions or reduce the laxity between the anal canal epithelium and the muscle to prevent the mucosal prolapse. These objectives can often be achieved by outpatient treatment and surgery avoided.

External haemorrhoids are vascular plexi beneath the perianal skin and are often unrelated to internal haemorrhoids. Bleeding from an external haemorrhoid can produce a perianal haematoma, which is extremely painful but usually starts to resolve spontaneously within a few days, often with the formation of a perianal skin tag.

Treatment of haemorrhoids

A large number of proprietary topical treatments exist. These usually contain a mixture of steroid and barrier cream. They provide symptomatic relief for an inflamed haemorrhoid or for perianal skin damaged by faecal seepage, but will not result in resolution of the underlying haemorrhoids and more definitive treatment may be required.

OUTPATIENT TREATMENT OF HAEMORRHOIDS

Small haemorrhoids can be treated by occluding the feeding vessel to prevent the inflow of blood. These treatments are usually effective for 1st degree and small 2nd degree haemorrhoids. Larger haemorrhoids may require several treatments at 6-week intervals and may not resolve. The feeding vessels enter the haemorrhoid proximally, well above the dentate line in the insensate rectal mucosa. Provided treatment is at this level, little pain results and the procedure can be carried out through a proctoscope in the awake patient. Several options exist for occluding the feeding vessel.

Sclerotherapy

A submucosal injection of 5 per cent phenol in almond oil causes both thrombosis of the feeding vessels and fibrosis, which tethers the lax mucosa, thus reducing prolapse. Injection of 2–3 ml immediately above each haemorrhoid should be seen to raise a pale swelling, which spreads in the submucosal plane. A white wheal indicates too superficial an injection into the mucosa. Too deep an injection anteriorly may have serious consequences; in men, chemical prostatitis and impotence are rare but well-recognised complications, and anovaginal fistulae have been reported in women. Minor septic reactions are not uncommon and occasionally, as with all haemorrhoidal treatment, severe sepsis can occur.[2]

Infrared photocoagulation

With infrared photocoagulation (IRPC) an infrared radiation source is applied immediately proximal to the upper margin of the haemorrhoid. The feeding vessel is thrombosed and a small white patch of mucosa is seen as a consequence of the thermal damage.

Banding

To band a haemorrhoid, the mucosa immediately above the haemorrhoid is drawn into a suction device, which then deploys a rubber band over it. The contained mucosa and vascular plexus are strangulated and separate at around 10–12 days. Banding is more effective for prolapsing (2nd and 3rd degree) haemorrhoids than sclerotherapy or IRPC, but even when the band is safely above the dentate line, the occasional patient experiences severe pain a few hours later and, in general, discomfort is more common. A secondary haemorrhage, which is occasionally profuse, may occur as the strangulated tissue separates.

Surgical treatment of haemorrhoids

CIRCULAR STAPLING OR ANOPEXY

This method has the disadvantage of the high cost of a disposable stapling device. It is normally performed under general anaesthesia, but postoperative pain is usually minimal as there is no wound below the dentate line. A circumferential mucosal purse-string suture is first placed *per anum* 3–5 cm above the dentate line, so that tightening of this purse-string will draw mucosa and submucosa into the stapler. When the stapler is closed and fired, a ring of staples is delivered and a 'doughnut' of mucosa and submucosa excised, which includes the arterial inflow to the upper end of the haemorrhoids. Vascularity is reduced and prolapsing haemorrhoidal mucosa is drawn back up into the anal canal. More widespread use is limited by cost and is also related to concern over complications. Too low a purse-string results in severe pain, while a purse-string that is too deep and incorporates muscle results in a full-thickness circular excision with the potential to cause pelvic sepsis or a rectovaginal fistula.

HAEMORRHOIDAL ARTERY LIGATION

In a haemorrhoidal artery ligation operation (HALO) the arteries feeding the haemorrhoidal plexus are ligated to reduce the inflow. Postoperative pain is again usually minimal. A special proctoscope containing a doppler ultrasound probe is used to identify the site of the haemorrhoidal arteries. The probe is then removed and a figure-of-eight suture placed deeply through the rectal mucosa at the site of the identified vessel several centimetres above the dentate line. The suture is tied, using a knot pusher, to occlude the feeding vessel. The same suture can then be used to plicate the haemorrhoidal tissue by taking a series of bites down to just proximal to the dentate line. When the suture is again tied, any prolapsing component of the haemorrhoid is drawn back above the sphincters. The proctoscope is then turned, and the procedure repeated at further sites where arterial blood flow is detected by the ultrasound probe. Often 6–7 vessels are detected and all should be ligated.

MILLIGAN–MORGAN HAEMORRHOIDECTOMY[4]

In this classical operation, haemorrhoidal tissue is excised radially at one or more sites, and each excision includes the external skin component of the haemorrhoidal complex in continuity with a strip of anal canal mucosa and the underlying haemorrhoidal plexus (Figure 24.4). Adequate bridges of skin and mucosa must be left intact between the excisions to prevent anal stenosis developing during healing. This is particularly important in the anal canal below the dentate line and at the anal verge (Figure 24.5). The dissection is in a deep submucosal plane between the haemorrhoidal plexus and the internal sphincter muscle, which must be identified and preserved. An anal retractor to retract, but not overstretch, the anus can make identification of the internal sphincter easier. It will also keep the other haemorrhoids out of the operative field, and it is rotated to display each haemorrhoid in turn.

Operative procedure

An artery forceps is applied to the skin element of each haemorrhoid and a second forceps applied to its prolapsing mucosa. These artery forceps hold the haemorrhoid for dissection, but they can also be used to retract the others out of

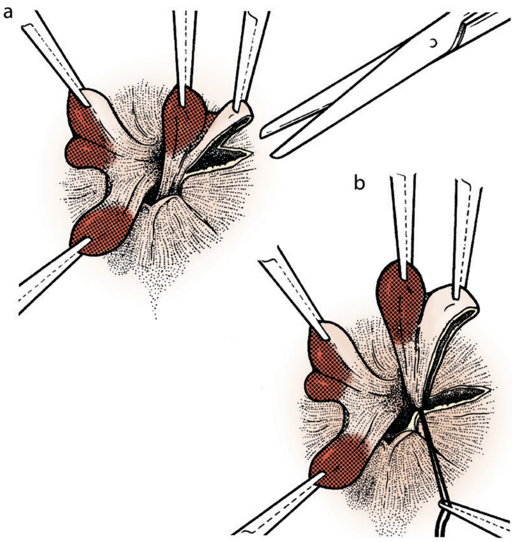


Figure 24.4 *The classic Milligan–Morgan haemorrhoidectomy. (a) An artery forceps has been applied to the skin and to the mucosal elements of each haemorrhoid. A* **V**-*shaped incision is made beneath the external skin element of the haemorrhoid and the haemorrhoid is dissected off the underlying internal sphincter. (b) The mucosal and submucosal pedicle at the proximal extremity of the haemorrhoid is transfixed and ligated.*

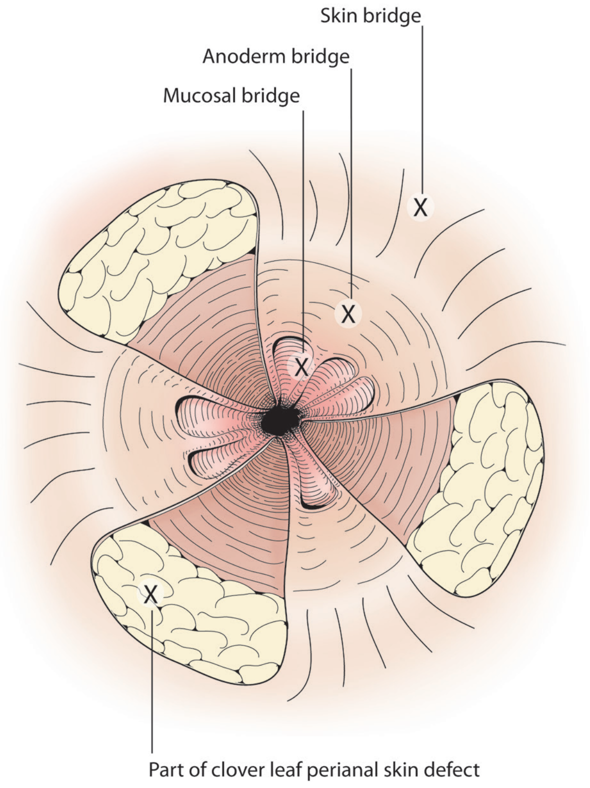


Figure 24.5 *A clover leaf-shaped defect in the anal canal and perianal skin will be left after a haemorrhoidectomy. It is important that intact bridges of mucosa, anoderm and perianal skin are retained.*

the operative field if an anal retractor is not employed. It is often easier to mark all the incisions in the anal canal, to ensure adequate skin and mucosal bridges between the excisions, before proceeding with the removal of the first haemorrhoid. A fine diathermy point is ideal for this as it incises the anoderm and mucosa with minimal bleeding. Excision of the first haemorrhoid is then commenced with a **V**-shaped incision through the skin at the base of the external component (Figure 24.4a). The **V**-incision is extended across the anal verge to join the preliminary superficial marking incisions and defines the tissue to be excised. The dissection is deepened under the **V** to develop the plane outside the haemorrhoidal tissue, but great care must be exercised to ensure that this dissection is *inside* the internal sphincter. The muscle fibres should be clearly visualised and preserved. The haemorrhoidal tissue is dissected off the underlying internal sphincter up into the anal canal until it is only attached by its pedicle of mucosa and the feeding vessels of the plexus. This pedicle is either secured by a transfixion suture or simply divided by diathermy and the haemorrhoid removed (Figure 24.4b). The surgeon is often concerned by the residual haemorrhoidal tissue left *in situ* under the bridges of stretched and prolapsed mucosa and anoderm. In almost every patient, healing with scar contraction draws this tissue back into the anal canal and reattaches it to the muscle coat.

Later modifications

- *Closed Ferguson haemorrhoidectomy*. On completion of the operation the mucosa and skin can be closed with absorbable sutures. Haemostasis must be meticulous or an infected haematoma will form deep to the closure and disrupt it.
- *Park's submucosal excision* differs in that a linear radial incision is made over the haemorrhoidal tissue, which is then dissected out from beneath the anoderm and mucosa. No epithelium is excised and the wound is closed.
- *Radial clamps or staples* can be used to remove the lax, stretched anal mucosa and anoderm with the underlying haemorrhoidal plexus.[5] Both the linear stapler and the Ligasure™ technique follow similar principles to the traditional clamp and cautery favoured by Eric Farquharson (Figure. 24.6). In these techniques it is important not to include the internal sphincter and also to preserve it from thermal damage.

PERIANAL HAEMATOMA (THROMBOSED EXTERNAL HAEMORRHOIDS)

Evacuation of the haematoma, as for the drainage of a perianal abscess, may shorten the natural history, but conservative management is usually equally satisfactory.

ANAL TAGS

Anal tags may cause irritation and difficulties with hygiene, and a patient may request excision. The removal of small tags can be disappointing as a new tag sometimes forms on healing. Narrow-stalked tags can be simply excised under local

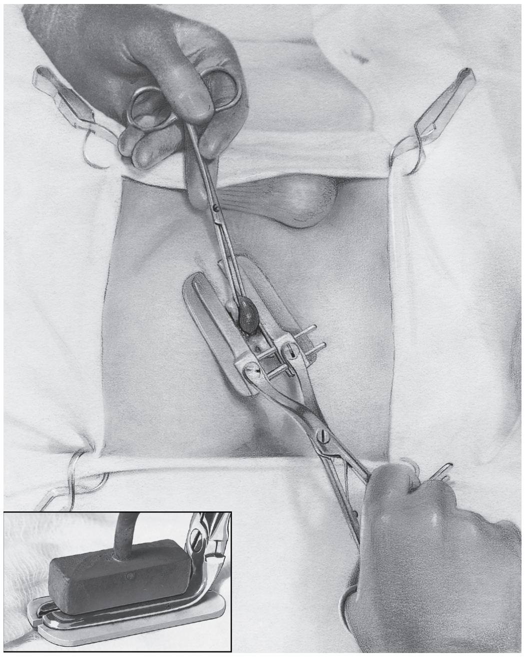


Figure 24.6 *A photograph from the original 1954 edition of a clamp and cautery haemorrhoidectomy in Eric Farquharson's unit.*

anaesthesia, but careful preoperative assessment is important. The tag may be a sentinel pile marking an underlying anal fissure or it may be the broad-based external component of an associated internal haemorrhoid. Treatment should then be of the underlying pathology, which is more likely than the tag itself to be the cause of the symptoms.

THROMBOSED PROLAPSED (STRANGULATED) HAEMORRHOIDS

Patients with prolapsed, thrombosed, mucosa-covered haemorrhoids are often in severe pain. Traditionally, surgery was postponed because of concern that intervention in the acute situation was associated with an increased risk of sepsis. Conservative treatment was aimed at pain relief. An anal stretch was effective, but only because it abolished anal spasm by partial disruption of the sphincters. Local applications of hyaluronidase or ice were also used, in addition to sugar or salt, to reduce swelling by osmosis. It is now considered more appropriate to simply proceed with a haemorrhoidectomy. However, great care must be exercised as the anatomical distortion may increase the risk both of sphincter damage and anal stenosis. It is usually advised that it is better to excise the largest, or at most two, haemorrhoidal areas rather than attempt a full haemorroidectomy.

ANAL FISSURES

Simple anal fissures occur almost exclusively in the midline, both anteriorly and posteriorly. The acute anal fissure is a radial split in the anoderm extending from the anal verge for a variable distance proximally towards the dentate line. These fissures are seen in association with constipation, childbirth and severe diarrhoea; straining with failure of relaxation of the internal sphincter may be implicated. Chronic anal fissures are those that fail to heal and form a linear, indurated chronic ulcer. Patients request treatment for defecatory bleeding and severe post-defecatory pain. There is considerable evidence that failure to heal is, at least in part, due to localised tissue ischaemia from a high anal pressure. A permanent surgical or temporary pharmacological reduction in resting anal pressure is the mainstay of treatment.

Fissures associated with Crohn's disease are often multiple, atypical and not in the midline. In general, surgery should be avoided. The surgeon must also be aware of other chronic ulcers in the anus including anal carcinoma and ulcers secondary to infection with cytomegalovirus (CMV) or syphilis.[1] If the aetiology is in doubt, and especially if squamous cell carcinoma is a possibility, the patient should be examined under anaesthesia, the fissure assessed, a swab taken for bacteriological investigations and a biopsy sent for histology.

Topical treatments are effective for most simple anal fissures. Glyceryl trinitrate (GTN) ointment (0.2%) is the most widely used, but its use is limited by severe headaches in some patients. A 2% solution of diltiazem is an equally effective alternative with fewer side-effects. Although some early relief may be achieved from reducing painful sphincter spasm, treatment should be continued for 6–8 weeks to allow time for the fissure to heal. Injection of botulinum toxin A into the internal sphincter also has excellent results, but it is expensive and usually requires a general anaesthetic.

A partial internal anal sphincter release is very effective in reducing resting tone, relieving the symptoms and healing the fissure. Many patients, however, will have a minor deterioration in continence and a few will have significant problems.[6] The increasing awareness that women with childbirth sphincter damage often compensate for many years and present in later life with incontinence has also raised surgical awareness of late morbidity from partial division of the sphincters. Sphincterotomy has therefore largely fallen out of favour, except where more conservative measures have failed and a patient is willing to accept the risk of impaired continence.

SUBCUTANEOUS LATERAL INTERNAL SPHINCTEROTOMY

Subcutaneous lateral internal sphincterotomy (SLIS) consists of partial division of the internal sphincter. The length of the fissure may be a good guide to the length of the release indicated. Inadequate release results in treatment failure and too generous a release increases the likelihood of passive incontinence.

Operative procedure

With the patient anaesthetised, the intersphincteric groove is palpable at the anal verge (see Figure 24.1). In the *open method* a 1- to 2-cm circumferential incision is made at the anal verge over the free edge of the internal sphincter. Blunt scissor dissection opens the plane inside and outside the internal sphincter to free it. The free lower edge of the internal sphincter is then grasped, drawn into the wound and its distal portion divided. In the *closed method*, a pointed no. 11 blade is introduced between the internal sphincter and the anoderm, with the blade orientated so that it lies parallel to the anal skin. It is then rotated to face outwards and gently pressed against the distal portion of the internal sphincter, which is held taut with a bivalve retractor. The scalpel is withdrawn and on digital palpation the tight band of the distal internal sphincter can be felt to have been released. Any residual band will 'give way' on gentle digital pressure on the anoderm over the area of the release. This is safer than reintroducing the scalpel. There is often an associated sentinel skin tag at the outer end of the fissure and sometimes a fibroepithelial polyp at the inner end. These should be excised. The wounds are left open.

ADVANCEMENT FLAPS

A chronic fissure, which has not healed on conservative management, may also be unsuitable for any form of sphincterotomy. For example, the patient may already have some impairment of continence or is known to have had external

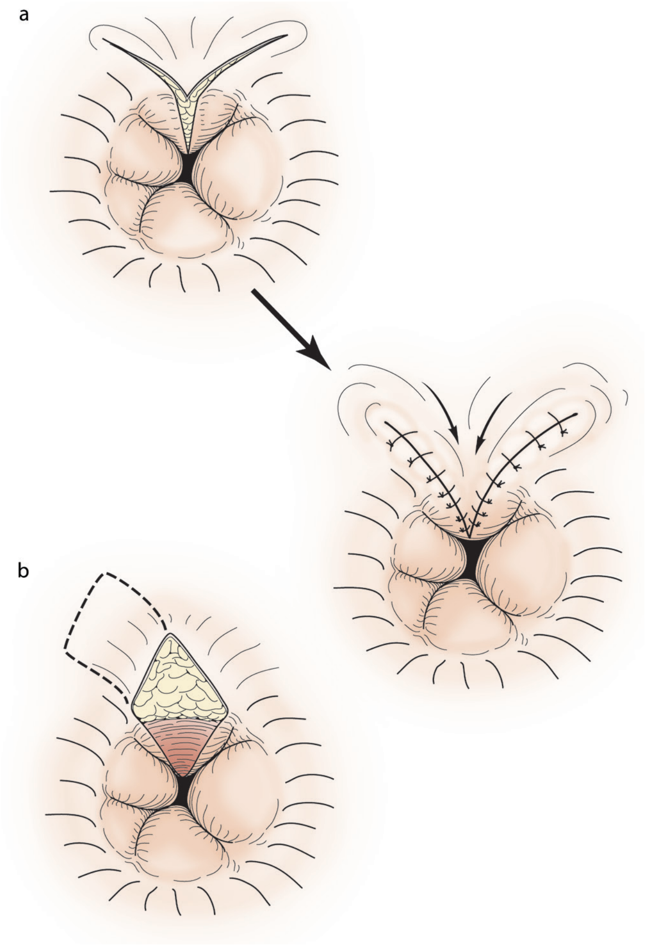


Figure 24.7 *(a) A **Y–V** anal advancement flap is a simple procedure for an anal stenosis. The **Y** incision at the anterior anal verge has been closed as a **V**, bringing extra tissue into the stenosed anus. (b) A chronic anal fissure can be excised and a local flap of healthy perianal skin and subcutaneous tissue brought in to fill the defect. The excision of this posterior fissure has left a diamond-shaped defect. The flap has been marked. It will be left attached to the underlying tissue from which it obtains its blood supply. The resultant donor defect can be closed or left to granulate.*

sphincter damage during a forceps delivery. Some fissures also occur in the presence of a low resting anal pressure, and sphicterotomy is not expected to heal these. Excision of the fissure and sentinel pile with preservation of the integrity of the internal sphincter can be followed by a diamond-shaped anal advancement flap to bring healthy, well-vascularised tissue into the fissure bed (Figure 24.7b).

ANAL SEPSIS

Anal and perianal sepsis are commonly confined to a compartment defined by muscle and fascial attachments (see Figure 24.1). These compartments are all circumferential and pus may therefore track around the anus in any plane (Figure 24.8). The circumferential tracking of pus is more frequent posteriorly, and has implications in the treatment of fistulae.

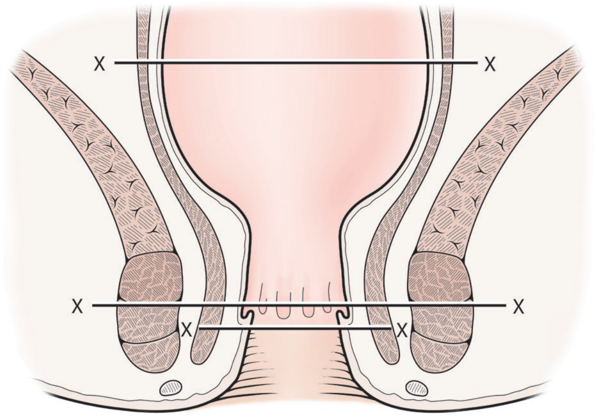


Figure 24.8 *Pus can track circumferentially in any perianal plane.*

Intersphincteric abscess

Most perianal sepsis starts in the intersphincteric space in association with infection within an anal gland. Occasionally, an intersphincteric infection will fail to point and present with severe anal pain without an obvious explanation. An MRI scan of the pelvis or, alternatively, an endoanal ultrasound under anaesthesia, will elucidate the underlying pathology. On other occasions the pus discharges spontaneously into the anal canal. If the patient is first seen at this stage, the atypical ragged ulceration can mimic more serious pathology. More frequently, the pus tracks down to the anal verge to present as a perianal abscess, or tracks through the external sphincter to form an ischiorectal abscess. Pus in all these abscesses has a potential or an established track to the lumen of the anal canal along the duct of the anal gland in which the infection originated.

Perianal abscess

A perianal abscess presents as a painful superficial swelling that distorts the anal verge (Figure 24.9). There may be a considerable collection of pus extending both cranially and caudally in the intersphincteric plane, and pus may even track up into the supralevator space (see Figure 24.11). Drainage is achieved with a cruciate incision over the swelling at the anal verge. The cavity is then deroofed, either with an elliptical incision or by the excision of the four flaps created by the initial cruciate incision, to allow good drainage (Figure 24.10). Any associated intersphincteric anal fistula should not be explored in the acute phase.

Ischiorectal abscess

An ischiorectal abscess presents with evidence of deep pus in the fat of the ischiorectal fossa, and the swelling is a few centimetres away from the anus (Figure 24.9b). In the early stages, fluctuation and erythema of the overlying skin may be absent. Treatment again consists of drainage and deroofing of this deep abscess is essential if drains or packs are to

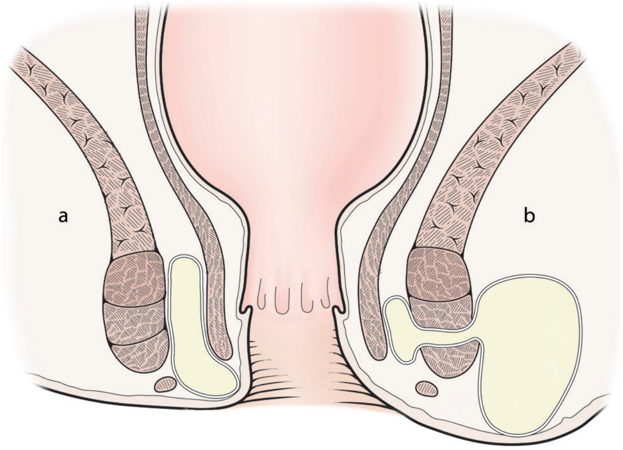


Figure 24.9 *Pus in the intersphincteric plane may track down to point as a perianal abscess (a), which distorts the anal verge. Alternatively, it may track through the external sphincter to form an ischiorectal abscess (b), which is deeper and points late to an area a few centimetres lateral to the anal verge.*

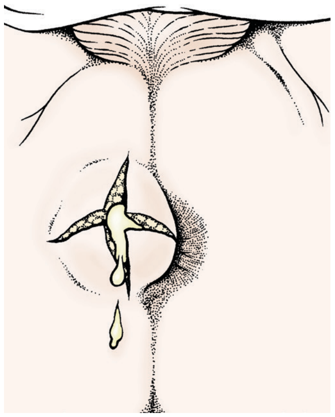


Figure 24.10 *A perianal abscess drained by a cruciate incision at the anal verge.*

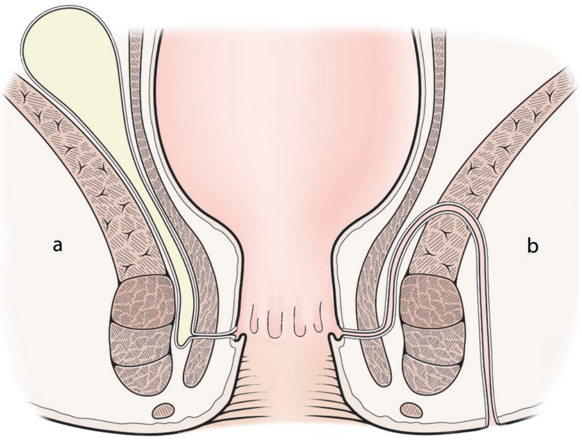


Figure 24.11 *(a) Intersphincteric sepsis can track up into the supralevator compartment. (b) Drainage of such an abscess through the levators will result in a suprasphincteric fistula. This is a high fistula despite an internal opening at the dentate line.*

be avoided. The incision must be sufficiently large to allow continued drainage of any residual pus and to prevent premature closure of the skin. A drain into the depths of the abscess is then often superfluous and increases discomfort. A temporary pack can be useful as a means of achieving postoperative haemostasis. Repeat packing is not recommended as it merely delays healing. The majority of ischiorectal abscesses are associated with an underlying transsphincteric fistula, following intersphincteric sepsis that has burst through the external sphincter. The fistula should not be explored, however, until the acute inflammation has settled.

Supralevator pus

Pus may extend cranially in the intersphincteric plane into the supralevator compartment (Figure 24.11a). However, pus can also track to this compartment from an ischiorectal abscess with a blind cranial extension penetrating the levator ani muscle. In addition, supralevator pus can be secondary to deep pelvic sepsis, and this pus may even track spontaneously down through the levators into the ischiorectal fossa. Pus above the levator ani muscles must therefore be carefully assessed, as inappropriate drainage from below can create a suprasphincteric or an extrasphincteric fistula. In Figure 24.11b, supralevator pus from a large intersphincteric abscess has been drained through the levator ani, with a resultant suprasphincteric fistula. When the primary pathology is located in the pelvis, associated with a paracolic abscess, an iatrogenic extrasphincteric fistula may result unless the sepsis is drained from the abdomen.

Severe perianal sepsis with spreading cellulitis

This is a life-threatening condition that is encountered almost exclusively in immunocompromised and diabetic patients. The infection is no longer confined to one compartment and it may be a spreading cellulitis or a necrotising soft tissue infection (see Chapters 2 and 4). Successful treatment depends on drainage of pus and excision of all dead tissue, combined with aggressive antibiotic therapy. Repeated examinations under anaesthesia are necessary to drain or excise areas that were previously deemed healthy but which have subsequently become involved. Faecal diversion by a colostomy is frequently necessary.

In the elderly debilitated patient an indolent variant of severe perianal sepsis is occasionally seen. An apparently minor infection is drained, but healing does not occur. Although there is minimal cellulitis or necrosis, the wound slowly extends and the sphincter muscles, lying exposed within it, are progressively destroyed. This distressing condition may occur during the last few days of life when pain relief is the only appropriate intervention. If more prolonged survival is likely, and the patient is fit for surgery, a defunctioning colostomy can be the best solution, both for control of the pain and management of the incontinence.

ANAL FISTULAE

Anal fistulae are classified on the relationship of the track to the sphincters. The definition of *high* or *low* describes the height of the track as it traverses the sphincter muscles and not the position of the internal opening, which is, almost without exception, at the dentate line. More accurate classification defines the relationship of the track to the internal and external sphincters separately, and it is on this information, and the underlying pathology, that surgical treatment is based.[7] Most fistulae are either *intersphincteric* or *transsphincteric*. Preoperative MRI scans are valuable, but sinograms and CT scans have not proved helpful. Intraoperative endoanal ultrasound is a valuable diagnostic tool for those experienced in its interpretation.

FISTULAE SECONDARY TO INTERSPHINCTERIC SEPSIS

The commonest anal fistulae are secondary to infection in an anal gland. Pus collects initially in the intersphincteric plane. It may track to the anal verge to present as a perianal abscess or break through the external sphincter into the ischiorectal fossa (see Figure 24.9). The fistula is formed by spontaneous or surgical drainage, which creates another channel into the abscess in addition to the opening of the anal gland at the dentate line. A primary track has been formed and continuing sepsis and poor drainage prevent healing. Bilateral circumferential tracking in a variety of planes (see Figure 24.8) is the aetiology of the posterior horseshoe fistula, with bilateral posterolateral tracks and external openings from a single internal opening (Figure 24.12). The blind extensions and secondary tracks of complex fistulae are created by the tracking of pus and the spontaneous or surgical drainage of these collections. Assessment of the anatomy is difficult, and previous failed attempts at surgery for these fistulae result in increasing complexity. Referral of patients with high and complex fistulae to colorectal surgeons with a special interest is advisable.

FISTULAE SECONDARY TO OTHER PATHOLOGY

Anal fistulae can develop secondary to other infective, inflammatory and malignant pathologies. They are common in tuberculosis and Crohn's disease. They also occur as a late complication of ileoanal pouch reconstruction surgery for inflammatory bowel disease.

Rectovaginal and anovaginal fistulae

Rectovaginal and anovaginal fistulae are a subdivision of anal fistulae and have a different spectrum of aetiology and management. They are short and lined with epithelium, and therefore resolution is unlikely without surgical repair. The fistula is often wider than other anal fistulae, allowing significant faecal contamination of the vagina. Excoriation of the vaginal mucosa is a major symptom even if faecal incontinence appears minimal. A rectovaginal fistula is extrasphincteric and an anovaginal fistula is either extrasphincteric or transsphincteric. A large anovaginal fistula is usually associated with a significant anterior sphincter defect. Rectovaginal and anovaginal fistulae may be secondary to intersphincteric anal gland sepsis, but more often are secondary to other pathology:

- *Mechanical and ischaemic*. These factors are often linked. In obstetric trauma, which is globally the commonest cause of rectovaginal fistula, the damage may be from direct tissue disruption or ischaemic pressure necrosis induced by the fetal head during a prolonged obstructed labour. Spontaneous stercoral perforation has a similar ischaemic aetiology. Radionecrosis, which is≈partially an ischaemic problem, can result in a fistula that may be difficult to differentiate from tumour recurrence. Purely mechanical causes include incorporation of the vagina in the staple line of a coloanal anastomosis.
- *Chronic inflammation*. Fistulae are associated with Crohn's disease and tuberculosis. A late pouch–vaginal fistula is common if an ileoanal pouch has been created

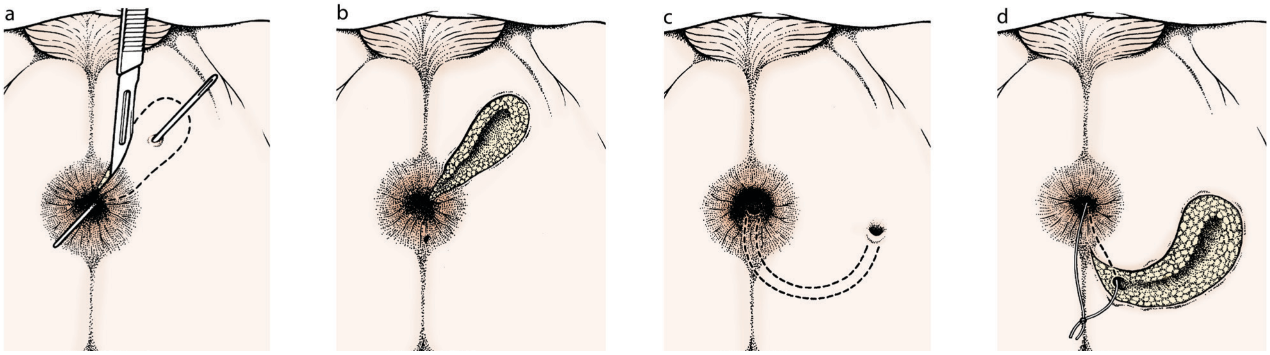


Figure 24.12 *(a) An anterior track is usually straight and radial. (b) The low anterior fistula has been laid open. (c) A posterior fistula is often curved and may have bilateral posterolateral external openings from a single midline internal opening. (d) The external portion of the track has been laid open, and the decision must now be made as to whether it is safe to lay open the part of the track that passes through the sphincter muscles.*

in a patient with Crohn's disease, and represents continuing Crohn's inflammation. However, late pouch–vaginal fistulae may occur secondary to simple cryptoglandular sepsis, deep pelvic sepsis or mechanical and ischaemic factors.

- *Pelvic sepsis*. An anastomotic break down of a coloanal or ileal pouch–anal anastomosis may present with a rectovaginal fistula. The initial anastomotic leak results in a pelvic collection, which then discharges into the vagina, or an infected haematoma discharges both into the vagina and into the lumen of the bowel through the anastomosis.
- *Malignancy*. A locally invasive, primary or recurrent, rectal or gynaecological malignancy may cause a rectovaginal fistula.

Colovaginal fistulae

Colovaginal fistulae occur when a pericolic abscess secondary to diverticular disease, Crohn's disease or a malignancy discharges into both the vagina and the segment of diseased colon. A sigmoid cancer lying folded down in the pouch of Douglas may form a colovaginal fistula by direct invasion of the vaginal vault. Colovaginal fistulae are more common in patients who have had a previous hysterectomy.

Surgery of anal fistulae

Examination under anaesthesia, with gentle insertion of probes to define the tracks, remains an important manoeuvre, despite increasing sophistication of preoperative and intraoperative imaging. Care must be taken not to create an additional internal opening by forcing the probe from a blind extension through the muscle and mucosa in the belief that there must be an opening in that position (Figure 24.13). The knowledge that anterior tracks are commonly radial, whereas posterior ones are more often curved, and may be horseshoe in configuration, arising from a midline posterior opening (Figure 24.12), will make it easier to follow a track. Injection of either hydrogen peroxide or a dye into the external opening to produce a bubble of peroxide or staining of the internal opening, respectively, are useful additional manoeuvres in some cases.

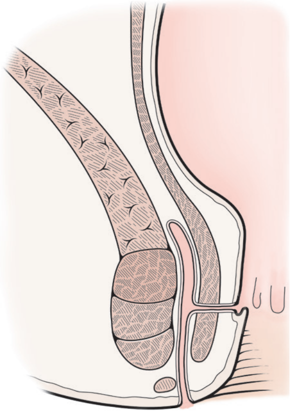


Figure 24.13 *This low intersphincteric fistula has a secondary blind extension up into the supralevator compartment. The probe may miss the internal opening and enter this extension. The probe must not then be forced through the bowel wall at the blind end on the assumption that there must be an internal opening at this point.*

LAYING-OPEN

Laying-open is the simplest definitive treatment of a fistula. A grooved probe is passed along the track, onto which an incision is made through anoderm, skin, fat and any sphincter musculature distal to the track itself. The edges are trimmed to marsupialise the track and prevent bridging-over during healing. Most fistulae were treated in this fashion when it was believed to be safe to sacrifice the entire internal sphincter and all of the external sphincter below the anorectal ring. Later, there was increasing awareness of impaired continence after a spectrum of minor anal procedures in which only an apparently insignificant proportion of the anal sphincters had been sacrificed or damaged. There was also concern that adverse effects could be delayed for some years, as after obstetric sphincter damage. Increasingly, other methods, which minimised division of the sphincters and were originally only employed for high fistulae, were explored. Surgical opinion varies,[8,9] but all would agree that laying-open remains a suitable technique for most intersphincteric fistulae when the proximal internal sphincter and the whole external sphincter can be preserved, and also for very low transsphincteric fistulae where less than one-third of the external sphincter is divided. Continence is a complex issue and, as discussed above, not solely dependent on the integrity or otherwise of the anal sphincters. Patients should therefore be warned preoperatively that there may be some deterioration in continence even when only a small portion of the sphincter is divided.

SETONS

A seton is a thread that is introduced along the track of a fistula and left *in situ*. This is a very old method of treatment both in Western and in traditional Indian medicine. Setons have been used in a variety of different ways, which determine the effect they have on the fistula track.[10] Setons have regained popularity recently and are currently used either as a loose draining seton or as a tighter cutting seton.

A fistula probe is first passed through the track. When a grooved fistula probe is used, a slippery thread such as Prolene™ can be threaded along the groove through the whole track of the fistula. Suture material that will not slide along the groove can be delivered into position by first passing a Prolene™ suture. The chosen thread is then tied to the Prolene™ and drawn through the track. Alternatively, a probe with an eye is passed through the track and the seton is threaded through the eye and drawn through the track as the probe is removed.

Loose seton

A loose seton ensures continuous drainage of any discharge and prevents premature closure of the external opening, which is the forerunner of recurrent sepsis. It is frequently a temporary measure to render a track more suitable for definitive treatment. A permanent loose, long-term seton may be the best treatment in some patients in whom more definitive surgery is likely to result in incontinence. As drainage is the most important goal, there should be no hesitation in laying open extensively any portion of the primary track, or extensions, outside the sphincters (Figure 24.14). Soft braided nylon (e.g. Ethibond®) is a suitable material, and is passed through the track as described above, after which the two ends are knotted together outside the anus to form a loose encirclement (Figure 24.14a). Simple removal of a loose seton after some months of good drainage will result in definitive healing in some patients. In Crohn's disease a loose seton may be placed temporarily to aid drainage of local sepsis and then removed after starting anti-tumour necrosis factor (TNF) therapy in order to allow healing.

Fibrin glue can increase the percentage of fistulae that will heal after removal of a seton to around 60 per cent. All sepsis must have been eradicated, therefore a period of loose seton drainage should always precede treatment if there is any significant sepsis. The seton is removed and granulation tissue curetted from the track. The nozzle of the injection kit is introduced into the external opening, and the two solutions of fibrinogen and thrombin are injected simultaneously until a bleb appears at the internal opening. The two solutions mix within the fistulous track and set. The anal retractor should be left in place for around 10 minutes until the bleb solidifies, as it is this plug at the internal opening that is critical for success. If treatment is unsuccessful and the fistula recurs, the procedure can be repeated.

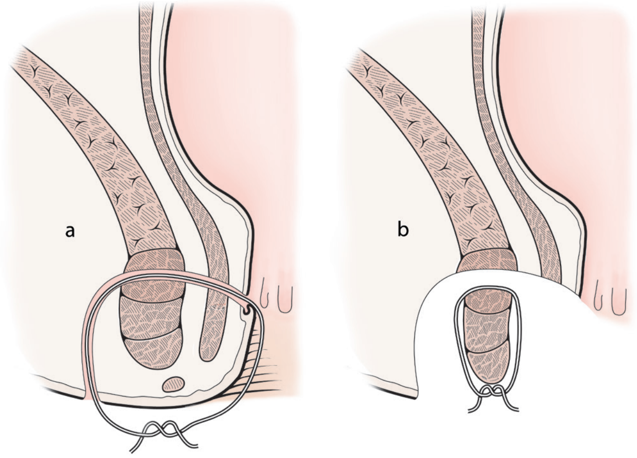


Figure 24.14 *A transsphincteric fistula, which is not suitable for a simple laying open of the track. (a) A loose seton through the fistula secures good drainage of the sepsis. (b) The fistula can then be treated with a cutting seton. The internal sphincter, anoderm and perianal skin below the track have all been divided and the seton has been tied snug around the external sphincter.*

A *fistula plug* can be sutured into the fistula track to occlude it. The plug material acts as a scaffold and tissue grows through it to occlude the track. Success rates are about 50 per cent, but are very variable between reported series.[11]

Cutting seton

A cutting seton is a definitive treatment of a fistula. A cutting seton works by slow division of the sphincters that it encircles, and the fistulous track becomes progressively 'lower' until finally the seton falls out. The advantage of the slow division of the sphincter is that only a small length of sphincter is divided at any one time and the portion sectioned is prevented from retraction by the intact sphincter above and below. In addition, there is inflammatory tethering of the cut ends of the sphincter muscle. Healing occurs sequentially from above downwards with a narrow fibrous scar, which in turn prevents retraction of the fibres of the next portion that is divided. There are, therefore, theoretical advantages over simple surgical laying-open of any transsphincteric track in which a significant portion of the sphincter mechanism must be divided. However, some surgeons argue that it merely prolongs the treatment in patients for whom laying-open was safe from the onset, and that in those in whom it was unsafe, incontinence will not have been avoided.

A period of loose seton drainage should be employed first if there is significant sepsis. The patient is then re-examined under anaesthesia and the skin, subcutaneous ischiorectal fat and anoderm overlying the track are divided. The internal sphincter is usually divided, although a seton can also be used around it. The track has now been laid open except where it passes through the external sphincter. The surgeon re-assesses what proportion of the external sphincter would be sacrificed if laying-open is to be completed, and makes a final decision on management. As some distal migration of the track is seen even with a loose seton, it may occasionally be judged to have become safe to divide the remaining sphincter below the track. When a cutting seton technique is used, a material such as silk (which causes an inflammatory reaction) is chosen, and this is tied snugly around the external sphincter muscle (Figure 24.14b). The seton will usually have cut through by 6–8 weeks. If, after this time, the seton is still *in situ*, a repeat examination under anaesthesia and replacement of the seton are indicated.

ADVANCEMENT FLAPS

Advancement flaps obliterate the internal opening and allow the fistula to heal. The surgery is technically demanding and performed through the anus. The position of the internal opening dictates the optimal position for surgery; the prone jack-knife position is more suitable for a rectovaginal fistula and the lithotomy position more suitable for a posterior fistula. A flap of mucosa with underlying internal sphincter, which ensures both blood supply and strength, is mobilised and advanced down to cover the internal opening (Figure 24.15). An alternative is a flap advanced up rather than down. Excellent results can be obtained, but often only by surgeons who perform these operations frequently.

TRACK EXCISION

A variety of techniques are based on the concept of excision of part, or the whole length, of the mature fistula tract, removing just the core of sphincter muscles through which it passes. This is a difficult operation, and the approach can be either from outside the sphincters or via the intersphincteric plane. Success is probably dependent on obliteration of the internal opening and eradication of residual intersphincteric sepsis, rather than complete excision of the track.

Surgery of rectovaginal fistulae

The true rectovaginal fistula is extrasphincteric and the anovaginal fistula is either extrasphincteric or transsphincteric. Simple laying-open techniques are therefore seldom satisfactory and some form of surgical repair is usually indicated. However, repair is not always possible or is doomed to failure. The surrounding tissue may be either scarred or ischaemic, whether compromised by previous infections, surgery or radiotherapy. There may be malignant invasion. Anovaginal fistulae associated with Crohn's disease are also prone to recur, even after seemingly successful surgery. Long-term loose seton drainage is sometimes of benefit, but has little to offer in a short, wide track with symptoms from faecal contamination of the vagina. Fibrin glue is also less successful in short, wide fistulae. Not infrequently, a patient with a rectovaginal or anovaginal fistula that cannot be repaired has to decide whether their symptoms are sufficiently severe that they would prefer to have a colostomy.

If repair is to be undertaken, an anal advancement flap, performed in the prone jack-knife position, is suitable for most small anovaginal fistulae. Larger, higher, true rectovaginal fistulae above the sphincters are more easily approached *per vaginam* or from the perineum, with the patient in the lithotomy position. Very high rectovaginal fistulae and colovaginal fistulae are approached from the abdomen. There are several planes between the vaginal and the rectal mucosa that can be entered from the perineum. For all surgery in this area, surgeons must understand in which planes they are working or damage to sphincters is inevitable. An intersphincteric dissection is appropriate for a small low fistula, but it is easier to extend the dissection more proximally for a higher fistula if an extrasphincteric approach is chosen. The choice of approach depends on access, the size and height of the fistula, the condition of local tissues and often, most importantly, the plane in which the surgeon feels most confident.

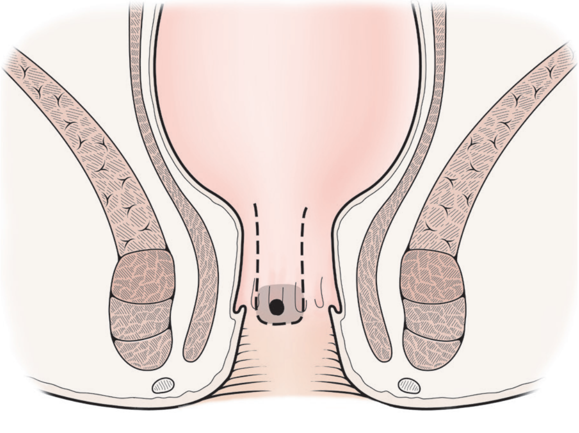


Figure 24.15 *A flap of mucosa, with the underlying internal sphincter, is mobilised and brought down to cover the proximal track The shaded area, which includes the internal opening, is excised.*

Post-partum anovaginal and rectovaginal fistulae

Post-partum anovaginal and rectovaginal fistulae are common in the developing world. They are mostly associated with prolonged or difficult deliveries, but they fall into three distinct categories:

- The first category is the result of a 4th degree perineal tear, and the anal sphincters are also disrupted. The emergency sphincter repair (described below) is combined with repair of the anal and vaginal mucosa. The tissue is healthy and immediate repair has a good chance of success. However, if the deeper aspects of such a repair fail, the patient may be left with healed perineal skin between the anal and vaginal orifices but an anovaginal fistula above, which is usually associated with significant anterior sphincter disruption.
- The second category is a tear above an intact perineum. The anal sphincters may be damaged or intact, and there may have been no significant perineal skin tear to alert the birth attender to the significant deeper damage. These fistulae are usually diagnosed a few days after delivery at the time of the first bowel movement.
- The third variety is encountered almost exclusively in areas remote from obstetric intervention. A woman has laboured unsuccessfully for days with a deeply engaged head and pelvic outlet disproportion. Eventually, a stillborn child is delivered but only after ischaemic pressure necrosis has occurred within the maternal pelvis. The most common damage is to the bladder against the pubis, and a vesicovaginal fistula forms (see Chapter 27). In more severe cases there is additional ischaemic pressure necrosis of the posterior vaginal wall and the anterior rectal wall, and a rectovaginal fistula develops. The perineal skin and anal sphincters are frequently undamaged. Diagnosis may be delayed for a week or more as the fistula only becomes apparent as necrotic tissue sloughs.

Repair of these fistulae depends on the time of presentation and whether a sphincter repair is also required. Unless the repair can be performed within 24 hours of delivery, a delay of 2–3 months is advisable and a defunctioning stoma may be required in the interim. A small fistula associated with a disrupted sphincter is best approached from the perineum. A larger, higher fistula is easier to repair *per vaginam*. The edges are excised and then each layer repaired separately starting with the rectal mucosa. Extensive dissection above the fistula and laterally in the plane between the vagina and rectum, increases tissue mobility and enhances the chance of success. The vaginal suture line should be positioned, if possible, so that it lies to one side of the rectal closure. Interposition of tissue between the mucosal suture lines is highly desirable. An anterior levatorplasty will achieve this or, alternatively, a Martius flap can be used. In injuries following pressure necrosis, tissue loss may be extensive and an abdominal approach may be necessary to bring down colon to form a neorectum.

LOCAL FLAPS

Local flaps provide tissue for interposition in the closure of rectovaginal fistulae. A *Martius flap* consists of the fat pad of a labium majus, with the underlying bulbocavernosa muscle, mobilised on a posterior pedicle containing the perineal branch of the pudendal artery. It is dissected out through a labial incision with the patient in the lithotomy position. The flap is swung through a subcutaneous tunnel to lie over the rectal closure (Figure 24.16). Alternatively, an island of skin with underlying fat, fascia and muscle can be cut from the perineal groin crease. The deep attachment of the flap is preserved to maintain blood supply, and it is then tunnelled under the lateral perineal skin to lie between the anus and vagina as a spacer (Figure 24.16). These techniques are particularly important when there is a large fistula with associated tissue loss from pressure necrosis, or when the blood supply to the tissues is poor from previous surgery or radiotherapy. Flap operations will be disappointing in the hands of the occasional operator, and referral to those with a special interest is recommended.

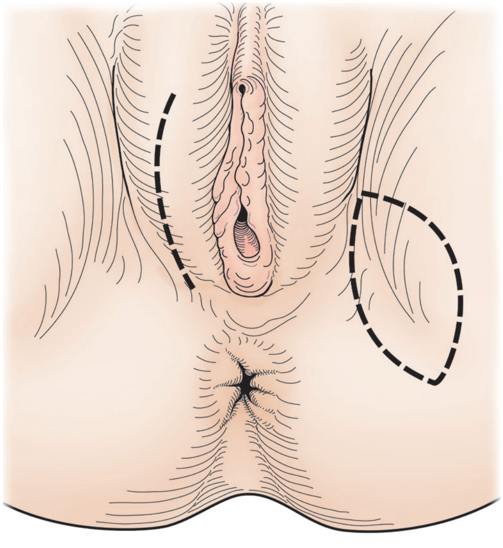


Figure 24.16 *Separation of the suture lines is desirable in the repair of vaginal fistulae. Local flaps can be utilised. A Martius flap consists of the bulbocavernosa muscle and fat elevated from the labium majus. The posterior pedicle is retained. This flap reaches with ease for a vesicovaginal fistula repair, but it can also reach for a rectovaginal fistula repair. An alternative flap can be obtained from the perineal groin crease.*

CROHN'S ANUS

Anal tags and fissures, recurrent anal sepsis and fistulae-in-ano are common in patients with Crohn's disease. In some patients, the anal pathology is incidental to their Crohn's disease, and no histological evidence of Crohn's inflammation is found in anal biopsies. Treatment follows the same principles as outlined above. In other patients the anus is involved in the Crohn's disease, and in these cases there may be associated Crohn's proctitis or the rectum may be spared. Intensive medical treatment, with antibiotics and immune modulation, is frequently very effective, at least in the short term. Surgical treatment of these fissures and fistulae should be as conservative as possible, and the underlying pathology must not be ignored. For example, a Crohn's fissure is a deep inflammatory ulcer and not a mechanical tear, and a Crohn's fistula has granulomatous inflammation along it in addition to bacterial infection. Attempts at flap advancement techniques will usually fail, and great reliance is placed on loose setons to prevent recurrent sepsis.

A colostomy diversion may bring some temporary relief, but seldom long-term gain after stoma reversal. A permanent colostomy without proctectomy does not prevent the continuing perineal sepsis. Many patients eventually require proctectomy, either for recurrent sepsis or for incontinence, which may in part be due to iatrogenic sphincter damage during attempts at surgical treatment. The prognosis is worse in patients who have rectal involvement, particularly if there is an anorectal stricture or supralevator induration. Healing of the perineum after a proctectomy for anorectal Crohn's may be very protracted. Medical treatment of the underlying Crohn's, in particular with anti-TNF therapy, is often effective, but sepsis should be under control before starting immunosuppressive drugs.

SURGERY FOR FAECAL INCONTINENCE

Conservative treatment for faecal incontinence will be the best option in many patients. Loperamide is used to reduce stool frequency, and the more solid stool also results in easier control. Biofeedback exercises help to build the strength of the external sphincter muscles and improve their coordination. Suppositories, enemas or irrigation can be used to ensure the rectum is empty and prevent passive leakage of rectal contents. Any underlying pathology causing diarrhoea or reduced rectal capacity, such as malignancy or colitis, should be considered and treated. With the exception of acute sphincter injuries, surgery is usually only considered once conservative measures have been tried and failed.

Unfortunately, many patients with incontinence cannot be helped by sphincter surgery or sacral nerve stimulation. If conservative measures have also failed, a colostomy may be an acceptable solution; an anus with no functioning sphincter is in essence a perineal colostomy to which no stoma bag can be attached.

Careful preoperative sphincter assessment, both anatomical and physiological, is essential prior to any surgery for incontinence. Anatomical disruption of the external sphincter can be repaired with good short-term results, but longer follow-up shows deterioration in continence over time. Surgical repair of the internal sphincter is less satisfactory. Poorly functioning but intact sphincters are also a common cause of incontinence. Operations to shorten lax sphincters by plication or to increase pelvic floor support by approximation of the levator muscles, have generally been disappointing. Plication of the levators behind the anus has the added theoretical advantage of restoring the anorectal angle, but the functional benefit is often only temporary.

The decision to offer sphincter surgery is relatively straightforward if the patient has a complete external sphincter disruption with major urge incontinence developing at the same time. Many, however, have only impaired continence, often developing some years after the sphincter injury. Investigations may confirm a partial tear. If a surgical repair is undertaken but breaks down, the patient may have continence inferior to the preoperative level. The patient must be aware of the risks and limitations of surgery.

Emergency sphincter repairs

Emergency sphincter repairs are most commonly performed by obstetricians as part of the deeper perineal muscle repair of an episiotomy or tear in childbirth. Operative conditions are seldom ideal, and the extent of the damage to the external sphincter may not be appreciated. Despite this, many heal satisfactorily.

When major sphincter damage is associated with a perineal tear that extends to the anal verge and into the anorectum, the severity of the injury is recognised at delivery. A general surgeon with experience in perineal surgery should be involved in the primary repair whenever possible. The repair should be undertaken under optimal operative conditions some hours after delivery. Working from the vagina, with the patient in the lithotomy position, all layers starting with the anorectal mucosa are identified, cleaned of faecal contamination and anatomically approximated. A defunctioning stoma will give the best chance of good healing if the anorectal mucosa is torn, but the patient may be reluctant to consider this. Similar principles apply to traumatic sphincter damage from perineal impalement injuries.

The occasional patient presents several days or weeks after delivery with an obvious sphincter disruption as part of an episiotomy that has broken down, and this may even be associated with the development of an anovaginal or rectovaginal fistula. Secondary repair should be delayed for some months, as all the tissue will be too friable for a satisfactory repair at this stage. If there is a significant rectovaginal fistula or complete incontinence, faecal diversion with a temporary colostomy may be required in the interim.

Elective sphincter repair

Elective repair of an external sphincter defect is most often undertaken months or years after major sphincter damage sustained in childbirth or during anal surgery. Good operative conditions are essential, with the patient in either the lithotomy or the prone jack-knife position.

The incision is made just outside and parallel to the anal sphincters at the site of the defect (Figure 24.17). Dissection

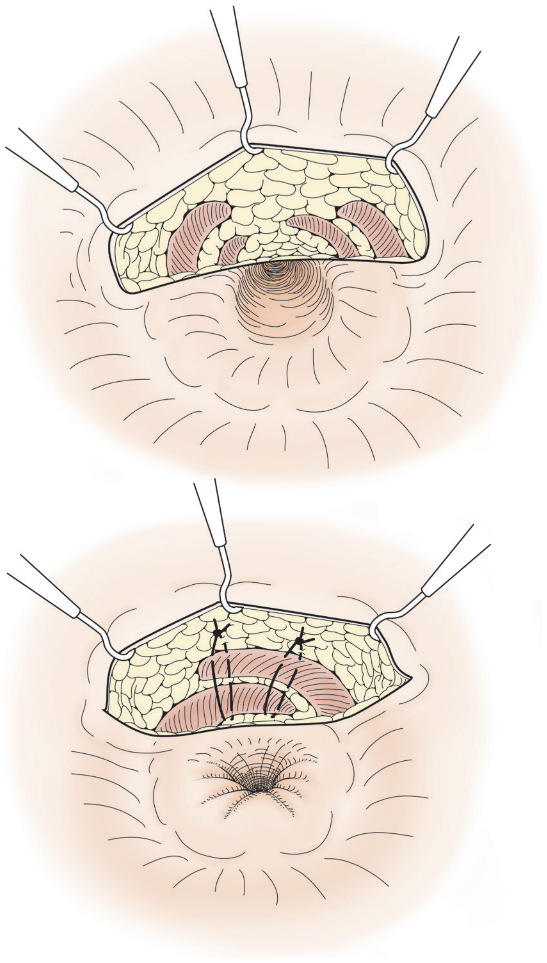


Figure 24.17 *External sphincter repair. A curved incision is made just outside the pigmented perianal skin. The ruptured ends of the sphincter are identified in the fat, mobilised and repaired with overlap.*

proceeds in the extrasphincteric plane until the sphincters are defined. The divided sphincter ends will have retracted circumferentially, but will also be displaced laterally from their normal position. The external sphincter twitches when touched with diathermy, whereas there is no response from perineal scar tissue or the internal sphincter. This sign can be very useful in a difficult operation. Dissection is continued to mobilise the external sphincter over about one-third of its circumference. Any fibrous connection between the disrupted muscle fibres is divided, but not excised. An overlap repair is then performed with non-absorbable Prolene™ or a long-acting dissolvable suture (Figure 24.17). An infected haematoma is a potential cause of breakdown of the repair, and both meticulous haemostasis and antibiotic prophylaxis are important. A repair will often have changed the orientation of the skin incision from transverse to longitudinal as the anatomical configuration of the perineum is restored, and the skin should be closed in the axis in which it lies most naturally. A small portion of the wound should be left open to facilitate free drainage of any serosanguineous collection. Postoperatively, antibiotics and stool softeners are continued.

Lateral defects in the external sphincter are less common than anterior defects and are more often iatrogenic in aetiology. Repair is complicated by the lateral innervation of the sphincters and nerve damage during the dissection is a risk. A nerve stimulator to identify the neurovascular bundle may be helpful.

INTERNAL SPHINCTER REPAIR

Internal sphincter repair is often unsatisfactory and is seldom attempted in isolation. In major disruption of both sphincters the whole sphincter complex may be overlapped as a single unit. It is, however, usually possible to identify the internal sphincter as a separate entity and it is then preferable to repair it separately. It is a thin sheet of muscle, which can be sewn with a continuous suture. Prolene™ sutures so close to the anoderm cause irritation and a long-acting absorbable suture is preferable.

Sacral nerve stimulation

Sacral nerve stimulation uses a permanently implanted pulse generator similar to a cardiac pacemaker to provide electrical stimulation of the S3 or S4 nerve root. Although a number of potential mechanisms of action have been suggested, it remains unclear precisely how it works. It can be effective in patients with faecal incontinence for a variety of reasons, including those with unrepaired internal or external sphincter injuries.[12] It has also shown promise in the treatment of severe evacuatory disorders.

In order to assess the suitability of a patient for this procedure, a trial period of temporary stimulation is carried out. With the patient in the prone position, under general or local anaesthesia, a percutaneous electrode is inserted through the S3 or S4 sacral foramen. Electrical stimulation is applied to the electrode and contraction of the pelvic floor or plantar flexion of the halux confirms stimulation of the S3 nerve root. The electrode is connected externally to a reusable pulse generator, which must be carried by the patient for the 2–3-week trial period. In the 75 per cent of patients whose symptoms are controlled, a second operation is carried out to place a permanent electrode, attached to an implanted pulse generator, which is usually implanted in the buttock.

Artificial anal sphincters

The two techniques described below are associated with defecatory difficulties and late failure and, especially since the advent of sacral nerve stimulation, are only rarely performed:

- A *stimulated graciloplasty*, in which a gracilis muscle is wrapped around the anus, can restore continence. An implantable electric stimulator is necessary as otherwise the wrap of fast twitch fatiguable fibres functions merely as a stenosing device.
- *Artificial implantable mechanical sphincters* are beset with problems. Infection and extrusion occur and the high pressures required to maintain continence can cause ischaemic damage to the anorectal mucosa.

Other perineal repairs

LEVATORPLASTY

Levatorplasty consists of plication of the levator muscles either behind (*posterior levatorplasty*) or in front of (*anterior levatorplasty*) the anus. The approach is through the extrasphincteric plane. Two or three non-absorbable interrupted sutures are placed to approximate the muscle. The operation in isolation is generally disappointing in the long term, and is now most often employed in combination with a sphincter repair.

RECTOCOELE REPAIR

A rectocoele is a tissue defect in the rectovaginal septum, and the rectum herniates into the vagina above the sphincters. The initial disruption is almost exclusively associated with childbirth and although it occurs in isolation, it is also seen in association with a complete or partial anterior sphincter disruption. Many large defects are symptomless, but some patients complain of a lump in the vagina on straining and symptoms of obstructive defaecation. Surgical opinion varies as to the benefit of repair. Repair can be undertaken transvaginally, transanally, through the perineum or from the abdomen. A perineal approach is illustrated in Figure 24.18. A transverse perineal incision is made immediately posterior to the vagina and the plane dissected deep to the posterior vaginal wall as far as the upper extent of the rectocoele.

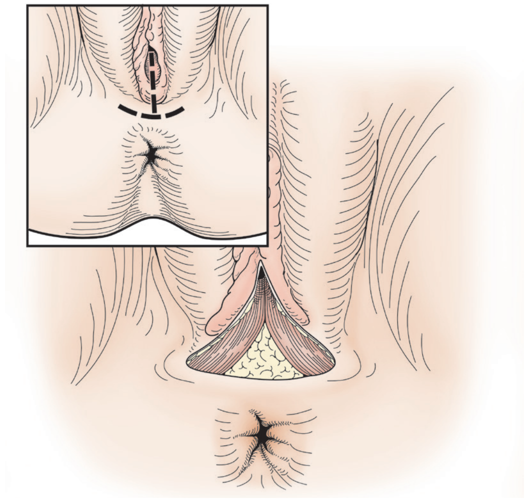


Figure 24.18 *Repair of a rectocoele. A transverse incision just posterior to the vagina is later extended by a vertical division of the posterior vaginal wall. The rectum is pushed posteriorly, and deep sutures are used to draw the puborectalis portion of the levators across between the vagina and rectum. The muscle is easier to feel than see, as it is covered with fascia and lying within fibro-fatty tissue.*

The vaginal wall is then divided vertically and the dissection carried laterally to expose the extent of the rectocoele.

Simple plication of the posterior vaginal musculature or rectal wall is employed by some surgeons, but most favour some form of additional support between the rectum and vagina. Ideally, the rectovaginal septal defect is defined and repaired. Unfortunately, it cannot normally be identified as a layer suitable for a strong sutured repair, and extra strength can only be obtained by deep sutures to draw the levator muscles into the midline from either side (Figure 24.18). Vaginal narrowing can be caused by this levatorplasty if too much tissue is drawn in. The vaginal mucosa and perineal wound are then closed and a vaginal pack for local pressure reduces the risk of a haematoma. Mesh is avoided because of the risk of infection, but can be used in the rectovaginal septum for support where additional pathology has made it more appropriate to perform the rectocoele repair from above.

RECTAL PROLAPSE

The number of operations designed to treat rectal prolapse is a reflection of the difficulties that surgeons experience in securing good long-term results. Both abdominal and perineal approaches to this condition have been extensively explored.

Abdominal rectopexy

An abdominal approach has a lower incidence of recurrence. However, it is a more major procedure for the elderly even when undertaken laparoscopically, and in younger patients the increased risk to the autonomic nerves and sexual function has to be considered. The rectum is mobilised out of the sacral hollow and fixed to the pelvic brim with non-absorbable sutures. Success is increased by adding a high anterior resection to the operation – a *resection rectopexy*. Mesh placed behind the rectum has generally fallen out of favour because of infectious complications and evacuatory dysfunction. Alternatively, after dissecting the rectum only in the anterior plane, mesh is attached to the rectum anteriorly and then anchored proximally to the sacral brim.

Perineal approaches

Perineal surgery for rectal prolapse is well tolerated even by the very elderly. Postoperative pain is minimal and most patients are fit for discharge home within a few days.

The operations are performed in the lithotomy position. The prolapse is encouraged to prolapse to its full extent by gentle retraction of the rectal wall out through the anus. A series of six to eight sutures is passed both through the skin at the anal verge and through more distant perineal skin. Once tied, they will evert the anal canal and form a simple means of retraction. Alternatively, a self-retaining ring retractor with skin hooks, as described above (p. 437), may be preferable. A dilute solution of adrenaline (1:400,000) is injected submucosally into the outer tube of the prolapse and the mucosa incised circumferentially with diathermy 1–2 cm above the dentate line for a Delorme's operation and 1 cm or so higher for an Altemeier's operation.

DELORME'S OPERATION

The mucosa from the whole prolapsed segment of bowel is removed, followed by reattachment of the proximal mucosal edge, with the underlying muscle of the bowel wall, to the initial circumferential incision just above the dentate line. Diathermy dissection in the adrenaline-filled submucosal plane can be relatively bloodless. Initially, the detached mucosa is lifted in forceps or rolled over a finger to display the plane for dissection (Figure 24.19a). The dissection is usually commenced anteriorly and the plane followed around each side to the posterior aspect of the prolapse. Difficulty will be encountered if the initial circumferential incision is not completed posteriorly, as the tethered mucosa will fail to lift and will tear. As the dissection reaches the apex of the prolapse, the mucosa forms a sleeve, which can be retracted to facilitate dissection on the inner surface of the prolapse (Figure 24.19b). Further adrenaline can now be injected into the submucosal plane of the inner tube. When no further mucosa can be prolapsed, the dissection is complete.

The first four sutures for mucosal apposition should also pass through multiple points in the denuded muscle of the bowel wall to plicate it (Figure 24.19c). It is important that mucosa does not retract, and the first three sutures should be in place before the mucosal tube is completely divided.

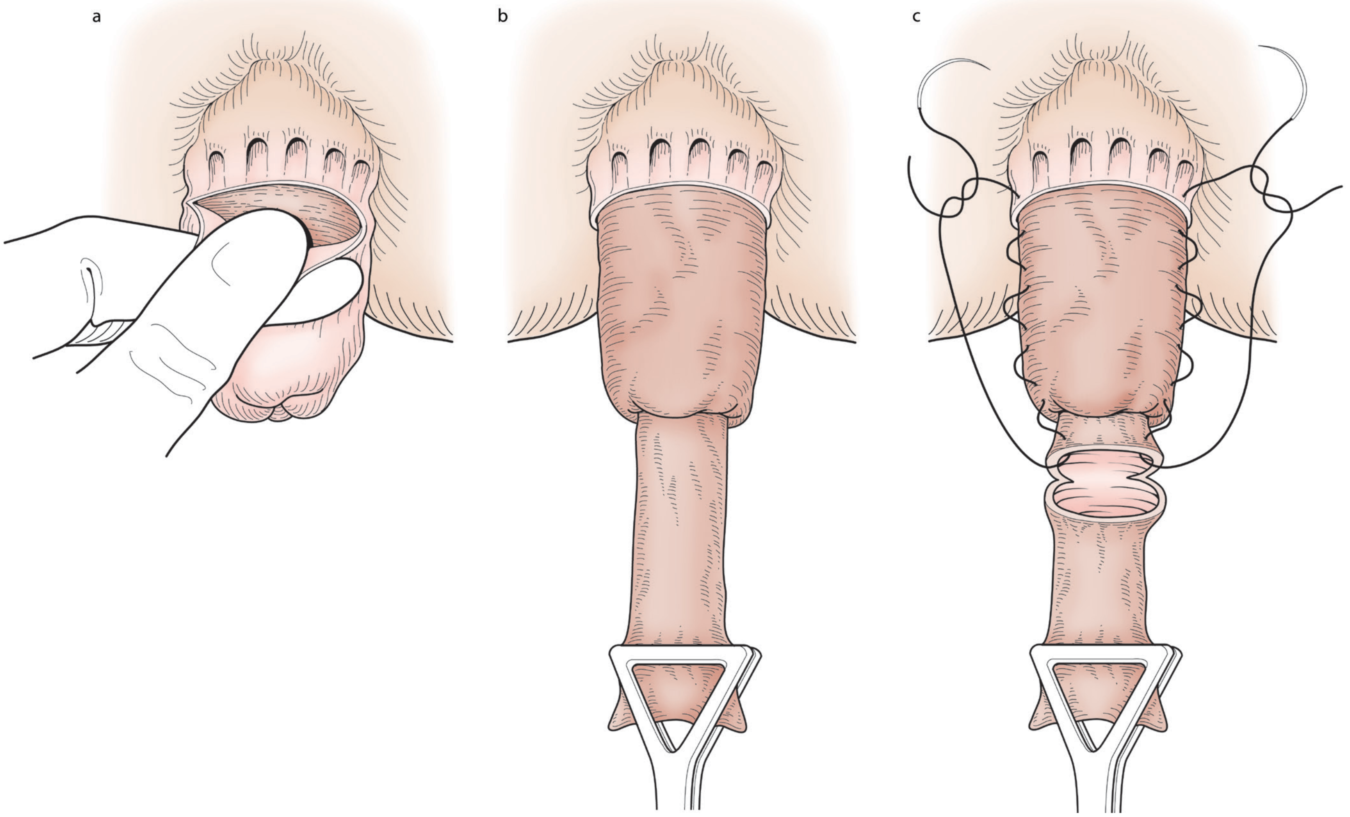


Figure 24.19 *Delorme's operation. (a) A circumferential incision is made through the mucosa 1–2 cm above the dentate line. The mucosa is separated off the underlying bowel wall. It is easily torn, and rolling it over a finger may be gentler than holding it with forceps. (b) The mucosa forms a tube once the dissection reaches the apex of the prolapse. (c) The lateral plication sutures include several bites of prolapsed muscle wall. In this diagram they are also forming the initial mucosal apposition sutures. (The anterior suture has been omitted from the drawing.)*

Once all four sutures are in place they are tied, and the muscle tube is reduced back inside the anus as a bulky ring. The ends of these initial sutures are left long and held in forceps so that retraction can facilitate the positioning of later sutures. A further 8–12 sutures complete the mucosal apposition. Each suture should include the muscle immediately deep to the mucosa for adequate strength, but no further deep plication is attempted. An absorbable suture that retains tensile strength for a few weeks is suitable, and Vicryl® is commonly used. The first sutures, which include the muscle plication, need to be heavier and stronger than subsequent sutures, which are solely for mucosal apposition. The anal verge retraction sutures are cut, or the skin hooks detached, and the suture line retracts within the anus.

ALTEMEIER'S OPERATION

Altemeier's operation is a perineal rectosigmoidectomy. The initial steps of the operation are similar to the Delorme's operation, but the circumferential mucosal incision is deepened through the full thickness of the bowel wall. This division is safely above the anal sphincters if the initial mucosal incision is placed correctly 2–3 cm above the dentate line. The prolapsed rectum then unfolds and is drawn out further through the anus as a single full-thickness tube along with its mesorectum. Anteriorly, a pocket of peritoneum in the rectovaginal pouch is also prolapsed (Figure 24.20). It must be entered and any small bowel loops replaced into the abdomen. Posteriorly, the mesorectum is drawn down with the rectum, and is separated from it by multiple ligations of

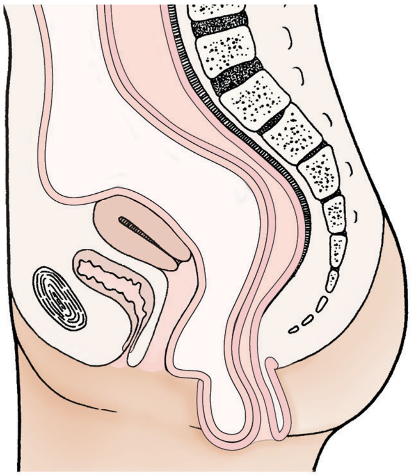


Figure 24.20 *Anteriorly, a rectal prolapse includes a prolapsed Pouch of Douglas. An understanding of this is essential in an Altemeier's operation.*

mesorectal vessels close to the rectal wall. The dissection is continued until further bowel is reluctant to prolapse. An initial division of part of the circumference of the bowel allows the first sutures of the anastomosis to be secured, as it is important at this stage that the bowel does not retract up into the pelvis. In contrast to a Delorme's operation, the sutures are not merely to achieve a mucosal apposition, but to form a full-thickness low coloanal anastomosis. However, the frequent leaks and major associated morbidity encountered in coloanal anastomoses after an anterior resection of the rectum are not a feature of Altemeier's procedure, possibly because of the retained mesorectum filling the pelvis.

Postoperative prognosis

Patients with rectal prolapse often have poor anal sphincters. The prolapse itself causes further stretching and laxity, and most patients are at least partially incontinent preoperatively. Some improvement can be expected with surgery, but the increased perianal muscle bulk after a Delorme's operation is an added advantage. A perineal operation can only deal with bowel that is already able to prolapse, and a high recurrence rate has disheartened some surgeons. However, the operation can simply be repeated a few years later.

PERINEAL APPROACHES TO THE RECTUM

The rectum may be approached surgically from the perineum and these approaches are discussed below. For some pathologies a combined abdominal and perineal approach is required and these procedures are described in Chapters 22 and 23.

Transanal approaches

A transanal approach is routinely used for endoscopic snare removal of benign polyps throughout the colon. In addition, direct surgical access through the anus allows surgical excision of benign tumours in the rectum. It may be possible to deliver a mobile polyp out through the anal sphincters (Figure 24.21). A higher, more broad-based villous lesion will have to be removed *in situ* through a proctoscope or anal bivalve retractor. Access is inevitably restricted as excessive anal dilation must be avoided. Elevation of the lesion off the underlying muscle by a submucosal injection of 1 in 400,000 adrenaline may be helpful in reducing bleeding and in identifying the optimal plane. A full-thickness excision can achieve complete removal of even a T2 rectal cancer, but the possibility of lymph node metastases will not have been addressed. This makes the technique unsuitable except in limited circumstances (see also Chapter 23). A mucosal defect is usually closed with absorbable sutures, and it was believed that this was mandatory after a full-thickness excision until it was shown to be unnecessary if the defect was below the peritoneal reflection.[13]

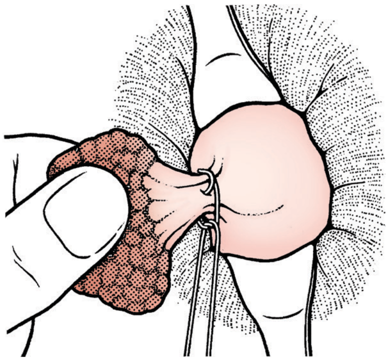


Figure 24.21 *Excision of a rectal polyp. It may be possible to prolapse a polyp on a stalk out of the anus for resection.*

TRANSANAL ENDOSCOPIC MICROSURGERY

Transanal endoscopic microsurgery (TEMS) uses a large operating proctoscope through which a binocular microscope can be introduced.[14] Excellent views can be obtained of rectal mucosa up to around 15 cm from the anal verge. The proctoscope is positioned to give a view of the rectal lesion and then fixed in position using an adjustable clamp to attach it to the operating table. The microscope is inserted and an insufflator attached. The proctoscope contains additional ports, which can be used to introduce specially designed graspers, suction, diathermy or ultrasonic dissecting instruments as required. The technique is similar to laparoscopic surgery. The surgery performed is the same as that carried out through a traditional transanal approach, but with the better view allowing a greater degree of precision and access to lesions higher in the rectum than would otherwise be possible.

The equipment is expensive and not every colorectal surgeon will wish to acquire the skills to perform these operations. This has therefore become yet another area of surgery where referral to colleagues with a special interest is routine. It must also be remembered that the same concern regarding possible lymph node metastases applies and many cases are technically possible but oncologically unsuitable.

Posterior approaches

The posterior approaches to the rectum, the posterior pelvic floor and the retrorectal space may be posterolateral between the sacrum and the pelvis, transverse between anus and coccyx or through the midline posteriorly. All of these approaches share the problem of limited access, the potential for autonomic nerve damage and the transgression of lymphatic channels in the mesorectum, making them unsuitable if malignancy is suspected. Additionally, when a posterior approach is combined with anal sphincter division and repair at the end of the procedure, breakdown of this can lead to incontinence. Access to the retrorectal space for excision of a benign developmental cyst is good, but if the anococcygeal ligament has to be divided for access, it should be reattached or contraction of the puborectalis sling will simply displace the anus forwards.

KRASKE OR SACRAL APPROACH

This is a midline posterior approach to the rectum. The skin incision is deepened onto the surface of the coccyx and lower sacrum. The muscle attachments to the sides of the coccyx are freed, and the anococcygeal raphe incised in the midline from the tip of the coccyx to the external sphincter (Figure 24.22). The coccyx is excised and if access is still insufficient, the 5th and 4th sacral vertebrae can be partially nibbled away in the midline. The 3rd sacral nerve should be preserved. Waldeyer's fascia is then incised and the posterior mesorectum exposed. After completion of surgery, Waldeyer's fascia is closed and the anococcygeal ligament and the muscular attachments to the coccyx approximated.

YORK MASON APPROACH

The patient is placed in the prone jack-knife position and a posterolateral incision is extended up from the anal verge. The bowel is incised in line with the skin incision from the anal verge upwards so that the anus and lower rectum can be opened out. The divided anal sphincters and the bowel wall are resutured on completion of the procedure. Excellent exposure of the anterior rectum is obtained,[15] but with the development of more sophisticated transanal techniques, there are now few indications for this operation.

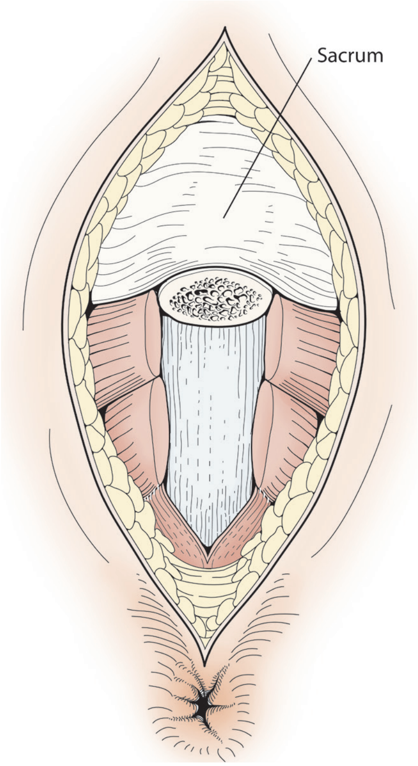


Figure 24.22 *The Kraske posterior approach. The muscles have been separated from their attachments to the coccyx, the anococcygeal raphe has been incised in the midline and the coccyx removed. Waldeyer's fascia is exposed.*

POSTERIOR SAGITTAL ANORECTOPLASTY

Posterior sagittal anorectoplasty is the standard paediatric surgical operation for the reconstruction of anorectal malformations. The patient is catheterised per urethra and placed prone with the pelvis elevated. The centre of the external sphincter is determined with a transcutaneous electrical muscle stimulator. Starting at this point, a midline sagittal incision is made, the length of which is determined by the complexity of the defect, but may be extended as far as the coccyx. Anteriorly, the incision is carried through the external sphincter to expose the fistulous connection. All tissue is divided exactly in the midline to avoid damage to important nerves. The rectum is opened and separated from the urinary tract or vagina. It is then mobilised and tapered to allow it to be placed within the limits of the reconstructed external sphincters.

Perineal excision of the rectum

This is usually a suboptimal operation for any malignant rectal lesion, as adequate excision of the lymphatic drainage is currently not possible without abdominal access. In the standard abdominoperineal resection for a low rectal cancer, a variable portion of the dissection is undertaken from below in a plane outside the anal sphincters. However, radical lymphadenectomy is performed from above (see Chapter 22).

Rectal excision for benign disease can be undertaken solely from the perineum when, for example, the colon has already been excised, the patient has an end colostomy and there is no other reason to re-enter the abdomen. The intersphincteric plane is entered at the anal verge, and the mobilisation continued as a close rectal dissection to remove the bowel but to leave the anal verge skin, the external sphincter and the pelvic floor musculature intact, in addition to retaining the mesorectum *in situ*. This approach is suitable for a short rectal stump, but there is a risk of damage to small bowel loops adherent within the pelvis. The Altemeier operation is in effect a 'close' rectal excision from below, but the intersphincteric plane is entered above the sphincter mechanism and not in the intersphincteric groove at the anal verge.

SURGERY FOR MALIGNANT AND PRE-MALIGNANT ANAL DISEASE

An anal cancer may be either an adenocarcinoma or a squamous cell carcinoma. The behaviour and management of the two tumours are very different. A preoperative biopsy for histology is therefore essential prior to any planning, as differentiation is not possible clinically.

An *adenocarcinoma* arising in the mucosa of the upper anal canal and anorectal junction behaves like an adenocarcinoma of the rectum and the treatment is primarily surgical. Direct extension, however, will occur early into the sphincter muscles and to obtain adequate clearance an abdominoperineal excision is usually inevitable except in very early tumours above the dentate line, which are still mobile on the external sphincter (see Chapters 22 and 23).

Squamous cell carcinomas arising from the squamous epithelium of the lower anal canal have a different behaviour and pattern of spread. Treatment is now primarily by chemoradiotherapy, and surgery is confined to a diagnostic biopsy and, possibly, construction of a defunctioning stoma during treatment if local symptoms are severe. Those cases that show only a partial response to chemoradiotherapy or relapse after completion of treatment may come to salvage surgery consisting of an abdominoperineal excision (Chapter 22). An inguinal node clearance may also be indicated as a salvage procedure (Chapter 25). The disease, or the treatment, may destroy the anal sphincters and in these patients a permanent left iliac fossa end colostomy is usually the best solution.

Anal intraepithelial neoplasia (AIN) appears as a patch of abnormal epithelium at the anal verge or in the perianal skin. Clinical suspicion is confirmed by biopsy or complete excision if the area is small. Mild degrees of dysplasia can be monitored over time, but severe dysplasia amounting to carcinoma in situ should be excised, as progression to invasive carcinoma is a significant risk.

PILONIDAL SINUS SURGERY

This apparently minor condition can present the surgeon with major challenges. The initial pathology is of one or more tiny deep midline pits in the natal cleft, which connect with a granulation tissue-lined cavity, lying in the subcutaneous fat and containing loose hairs. Recurrent infections occur in this cavity, which later extends under apparently normal skin, both in the natal cleft and laterally into one or both buttocks. Minor infections may settle on antibiotics, but if an abscess develops it will discharge or require drainage. The underlying disease remains, however, and repeated episodes of infection are likely.

Deroofing all sinuses and awaiting healing of the granulating wound is a long process. Excision and primary closure is another option when the disease is confined to the midline, but if the closure breaks down, a larger defect is left to granulate. With both techniques recurrence is common as hairs can later grow into the midline scars.

Two flap techniques, which avoid a midline scar and have proved very successful for advanced pilonidal disease, are described below.[16,17] They are unnecessarily extensive for early minor disease, for which a modification and simplification of the original Bascom procedure is more appropriate.

MODIFIED BASCOM PROCEDURE

The modified Bascom procedure is an ideal operation when there are no midline unhealed wounds, abscesses or scars. The patient lies prone and local infiltrative anaesthesia is satisfactory. The buttocks are strapped apart. Each pit is excised with the pointed no. 11 blade, removing a diamond-shaped piece of skin no larger than a rice grain, but the excision should extend deep for 2–3 mm to include the epithelialised portion of the pit. A 2–3-cm incision is then made 2 cm from the midline alongside the pits, on the side of any previous infection. A probe introduced into a pit may act as a guide if none is apparent (Figure 24.23). This incision serves three functions. Firstly, it is used to enter the sinus system and curette out all hairs and infective granulation tissue. Secondly, through it the midline skin is released from its tethering to the post-sacral fascia, and the depth of the natal cleft is reduced. Thirdly, as the incision is left open, it relieves any tension on the subsequent closure of the pits.

The buttock strapping is then removed to relieve tension and each pit excision closed with 5/0 Prolene™. Midline scarring may be minimised if the suture is introduced 1 cm lateral to the pit, continued around the pit in the subcuticular plane, brought out close to its initial insertion and tied. The remaining steps described in the original Bascom procedure, in which a fibro-fatty flap is rotated under the midline skin, are omitted. An antiseptic-soaked wick is simply tucked into the lateral wound so that it lies under the midline, and is removed after 48 hours. A course of antibiotics is given, the pit closure sutures are removed at 1 week, and healing of the

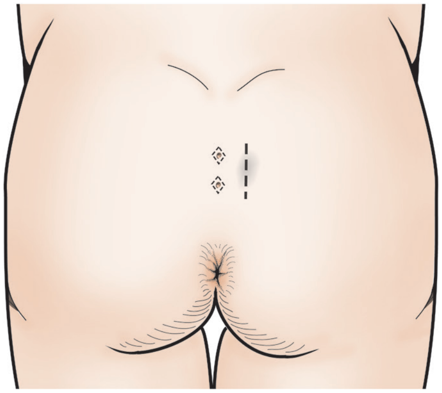


Figure 24.23 *A Bascom procedure. The lateral incision is alongside the midline cleft and is over the scar of any previous lateral abscess. Each pit is excised with a 'diamond' of skin, which must include all the epithelialised portion of the pit. The pit excisions are closed with fine subcuticular sutures and the lateral incision is left open.*

lateral wound is usually complete by 2 weeks. Obliteration of the pits is achieved and each leaves only a midline wound of a couple of millimetres in length. If there is recurrence and more radical surgery is indicated, the scars are within the area of skin that will be excised in either of the flap procedures described below.

KARYDAKIS FLAP

In this procedure an ellipse of skin and underlying fat down to the deep fascia is excised. The ellipse is parallel to, but 2 cm from, the midline. It must be at least 5 cm in length as there is increased tension on closure of a short ellipse. The medial side of the incision should just cross the midline and should encompass all the diseased midline tissue (Figure 24.24a). In extensive natal cleft disease a long ellipse may be required, but this does not create any problem. However, when there are bilateral sinus extensions it may not be possible to excise all diseased tissue with this technique. The ellipse must be symmetrical, and the surgeon must resist the temptation to cut the lateral part of the ellipse less generously in an attempt to remove less tissue, as this only results in the scar failing to lie away from the midline. The whole length of the medial side of the incision is then mobilised by undercutting a distance of 2 cm at a depth of 1 cm (Figure 24.24b). In thin patients the undercutting incision may be on the deep fascia. Any strapping to distract the buttocks is now removed. The first sutures are placed between the limit of the undercutting incision and the deep fascia in the midline (Figure 24.24c). These draw the flap over and create a new shallow midline sulcus. Pressure applied by an assistant to unroll the flap as the sutures are tied will reduce tension. A vacuum drain and a second layer of more superficial fat sutures are then inserted, and finally the skin is apposed with interrupted non-absorbable sutures. The wound lies a few centimetres from the midline and the patient has a new shallow natal cleft with healthy unscarred skin (Figure 24.24d).

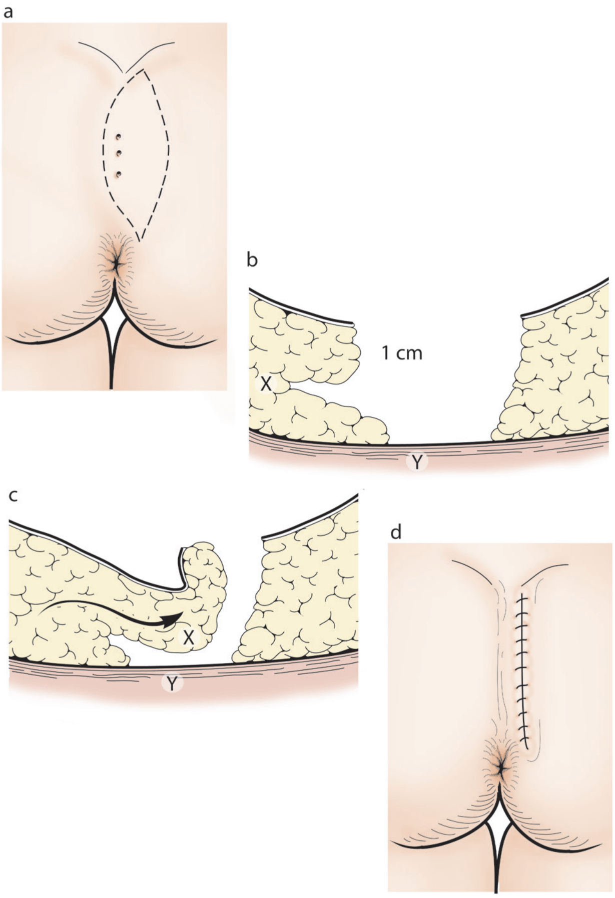


Figure 24.24 *Karydakis flap. (a) The long axis of the ellipse is parallel to the midline and 2 cm from it. The length of the ellipse must be such that the medial side of the ellipse crosses the midline to include all diseased midline tissue. The lateral side of the incision must be planned so that the ellipse is symmetrical. (b) An undercutting incision is made along the whole length of the medial side, 1 cm below the skin surface. This undercut should be extended out for 2 cm. (c) The medial flap is unrolled and advanced over the midline. Deep sutures are placed between points X and Y. (d) The final scar is not in the midline.*

LIMBERG RHOMBOID FLAP

The patient is placed prone and the buttocks are strapped apart. A rhombic area of skin and subcutaneous fat is excised, which includes both the midline pits and any lateral sinus extensions (Figure 24.25). (The long axis of the rhomboid is in the midline and its shape determined by angles of 60 degrees at **A** and **C** and 120 degrees at **B** and **D**.) Accuracy is essential and the tissue to be excised and the flap must be measured and marked at the start of surgery. Planning using precise angles is difficult and the following linear measurements are an alternative.[18] The line **A**–**C** is drawn and its length measured. **C** should be adjacent to the perianal skin and **A** is placed so that all diseased tissue can be included in the excision. The line **B**–**D** transects the midpoint of **A**–**C** at right-angles and is 60 per cent of its length. It is this ratio that determines the correct shape of the rhomboid. The flap is planned so that **D**–**E** is a direct continuation of the line **B**–**D** and is of equal length to the incision **B**–**A**, to which it will be sutured after rotation. **E**–**F** is parallel to **D**–**C,** and of equal length. After rotation, it will be sutured to **A**–**D**.

The skin and subcutaneous fat to be removed are excised down to, but not including, the deep fascia. The flap is raised so that it includes skin, subcutaneous fat and the fascia overlying gluteus maximus. It is then rotated to cover the midline rhomboid defect and the defect this creates can be closed in a linear fashion. Deep absorbable sutures, to include fascia and

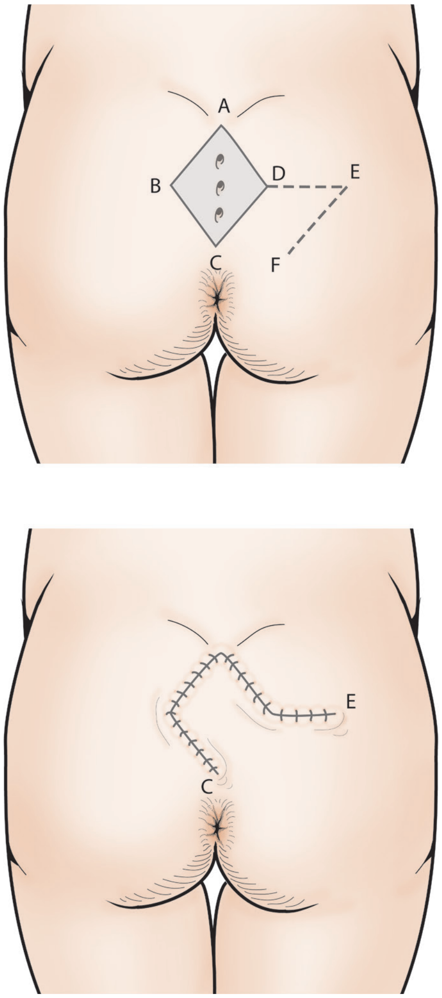


Figure 24.25 *Limberg rhomboid flap. Marking is essential.* ***B–D*** *is 60% of the length of* ***A–C****.* ***D–E*** *is a direct continuation of* ***B–D*** *and the same length as* ***A–B****.* ***E–F*** *and* ***C–D*** *are parallel and of the same length. The tissue within* ***A–B–C–D*** *is excised. A flap of* ***C–D–E–F*** *is mobilised on a pedicle of* ***C–F****.*

fat, are placed over a vacuum drain and then finally the skin is closed with interrupted sutures. This operation produces a tension-free flap of unscarred skin in the midline.

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SURGERY OF THE GROIN AND EXTERNAL GENITALIA

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INGUINAL HERNIAE

Surgery of the groin is dominated by that of inguinal herniae, and an understanding of the anatomy and development of the region is essential to the surgeon.

Anatomy

The *inguinal canal*, which is about 4 cm in length, runs obliquely through the muscles, aponeuroses and fasciae of the abdominal wall above the medial part of the inguinal ligament. Its internal end is the *deep inguinal ring*, an opening in the transversalis fascia, 1 cm above the mid-point of the inguinal ligament and immediately lateral to the inferior epigastric vessels. Its external end is the *superficial inguinal ring*, a triangular aperture in the aponeurosis of external oblique immediately above the pubic tubercle and the medial end of the inguinal ligament.

BOUNDARIES

The *anterior wall* is formed in its whole length by the aponeurosis of external oblique and in its lateral third by the lowest fibres of internal oblique arising from the inguinal ligament. The *posterior wall* is formed in its whole length by the transversalis fascia and in its medial half by the conjoint tendon. The *roof* is formed by the lower borders of internal oblique and transversus abdominis, which arch over the canal before fusing to form the conjoint tendon. The *floor* is the grooved upper surface of the inguinal ligament and its reflection onto the superior ramus of the pubis – the lacunar ligament.

CONTENTS

In males the main content of the canal is the *spermatic cord*, and in females it is the *round ligament*. The *ilioinguinal nerve* lies in the medial part of the canal and either emerges through the superficial ring or pierces the aponeurosis close to it. The *spermatic cord* consists of the vas deferens, with its accompanying small artery, the testicular artery and veins, and lymph vessels and autonomic nerves. The cord has three *coverings*:

- The internal spermatic fascia derived from the transversalis fascia at the deep ring.
- The cremasteric muscle and fascia derived from internal oblique.
- The external spermatic fascia derived from the external oblique aponeurosis at the superficial ring.

Development

The testis develops as a retroperitoneal, intra-abdominal organ that migrates into the scrotum during the last trimester of intrauterine life. Immediately prior to its entry into the deep ring, the testis and the testicular vessels are lying intraperitoneally. Migration down the canal and into the scrotum is guided by the gubernaculum and is associated with an outpouching of peritoneum, the *processus vaginalis*. An undescended or ectopic testis is the result of a failure of full testicular descent and is thus often associated with an indirect inguinal hernia. The fully descended testis projects into the distal part of the processus vaginalis, which forms the tunica vaginalis of the testis. The rest of the processus is usually obliterated. A wide persistent peritoneal tube is an indirect inguinal hernia sac extending into the scrotum. A patent peritoneal tube that is too narrow to allow herniation is described as a *persistent processus vaginalis*. It maintains the communication between the space around the testis and the peritoneal cavity, and an infantile hydrocoele of trapped peritoneal fluid forms. Obliteration may fail only in the proximal segment of the peritoneal extension. A short, wide persistent peritoneal tube then forms an indirect inguinal hernial sac confined to the groin, and a narrow tube may result in an *infantile hydrocoele of the cord*.

The inguinal canal in infancy and early childhood is proportionally shorter and less oblique than in the adult. The testis is commonly retractile in childhood, and may be withdrawn intermittently into the inguinal canal or even into the abdomen by cremasteric muscle contraction.

INDIRECT INGUINAL HERNIAE

The *sac*, or peritoneal tube through which the abdominal contents protrude, accompanies the spermatic cord in its oblique course through the inguinal canal. The neck of the sac, which is often constricted, lies at the deep inguinal ring, lateral to the inferior epigastric vessels (Figure 25.1a). The sac is enclosed within the coverings of the cord and lies anterior to the vas and testicular vessels. Many of these herniae are congenital, but they may remain as an empty sac for many years and present in adult life. Sliding indirect herniae also occur where a variable portion of the herniated tissue is extraperitoneal (see also Chapter 13).

DIRECT INGUINAL HERNIAE

A direct inguinal hernia traverses only the medial part of the inguinal canal and does not, therefore, pursue the oblique course taken by the spermatic cord. It protrudes from the abdominal cavity through the posterior wall of the inguinal canal medial to the inferior epigastric vessels (Figure 25.1b). The hernia seldom descends completely into the scrotum. The sac may be narrow-necked and protrude through a small posterior wall defect. More often, it is wider at its neck than at its fundus, and is little more than a bulging of the peritoneum as it protrudes through a wide defect. The hernia lies behind the spermatic cord and is covered by a thin, stretched fascial layer derived from the edges of the defect.

SELECTION FOR SURGERY

Treatment of inguinal herniae should be advised for all herniae that carry a significant risk of strangulation. Herniae that are difficult to reduce, and all herniae in infancy, are in this category.

Wide-necked direct herniae that reduce spontaneously, immediately on lying down, are very unlikely to strangulate. Many of these herniae are asymptomatic and, if the patient is elderly and an operation would entail a significant risk, there is little justification for surgery. Repair is, however, recommended for the majority of herniae in younger people, because even if they are asymptomatic and unlikely to strangulate, the natural history is for them to increase in size.

Incarcerated (irreducible) herniae should always be considered for repair unless the risks of surgery are exceptional. Certainly, any hernia that has only recently become irreducible is at high risk of progression to strangulation. Some long-standing but uncomplicated irreducible herniae may be left alone if not symptomatic.

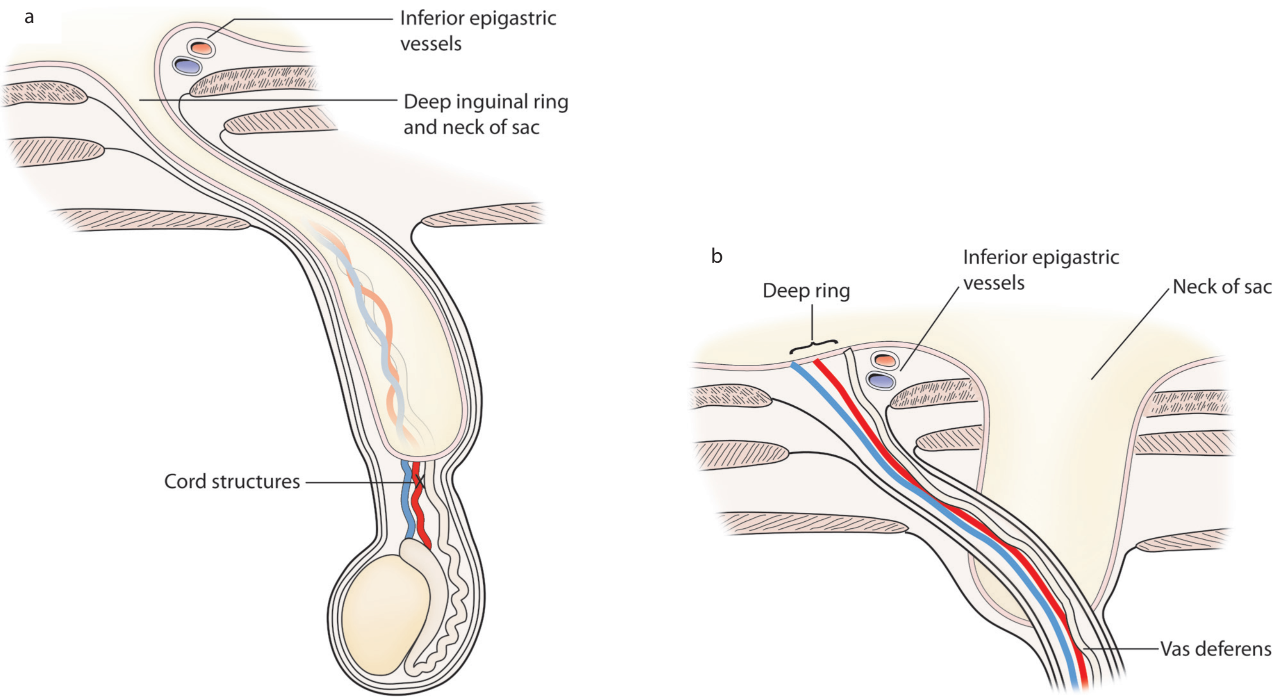
a
Inferior epigastric vessels
Deep inguinal ring and neck of sac
Cord structures
b
Deep ring
Inferior epigastric vessels
Neck of sac
Vas deferens

Figure 25.1 *(a) An indirect inguinal hernial sac traverses the oblique lie of the inguinal canal, which it enters through the deep ring lateral to the inferior epigastric vessels. It lies within the coverings of the cord anterior to the vas and vessels. Note the narrow neck of the sac. (b) A direct inguinal hernia enters the inguinal canal through a posterior wall defect medial to the inferior epigastric vessels. It lies behind the cord and its coverings. Note the wide-necked sac.*

Herniotomy

Herniotomy involves simple ligation and division of the neck of the sac. It is a satisfactory procedure for the congenital indirect herniae encountered in infancy, childhood and adolescence. Herniotomy is also probably all that is required in some young adults with a congenital indirect hernia and good inguinal canal musculature. Most surgeons, however, favour some form of posterior wall repair even in young adults, and all would agree that the risk of recurrence after simple herniotomy is unacceptably high in the middle-aged and elderly. A recurrent inguinal hernia is almost always direct regardless of whether the initial hernia was direct or indirect. Although the deep inguinal ring remains a point of potential weakness, as it cannot be closed unless the testis is removed, a recurrent indirect hernia is rare.

Herniorrhaphy

Herniorrhaphy implies some form of repair or reinforcement of the posterior wall of the inguinal canal. The repair in women is essentially identical to that in men except that the round ligament can be sacrificed and the deep ring closed. The posterior wall of the inguinal canal can be approached through the canal, and this is the most common route for open repair. An open pre-peritoneal approach from above the inguinal canal is preferred by some surgeons for bilateral repairs and for recurrences. This is also the approach used in the minimal-access extraperitoneal repair described below.

A great number of methods of repair of the inguinal canal have been employed over the past 130 years. Hernia recurrence appeared to be related more to the individual surgeon than to the method of repair employed, and only more recently have large multi-centre trials established that the most secure method, independent of surgeon bias, is the tension-free mesh repair popularised by Lichenstein. The *Shouldice* repair was regarded as the gold standard of open herniorrhaphy for many years, but it is more difficult to perform to the standard that ensures these excellent results.

Laparoscopic hernia repair has steadily gained popularity, especially for bilateral and recurrent herniae.[1] In expert hands the complications and recurrence rates are comparable with those of standard open groin repairs and postoperative recovery is faster. Additionally, the incidence of chronic groin pain is reduced. Disadvantages include the need for general anaesthesia and the cost of disposable laparoscopic instruments. The *transabdominal pre-peritoneal* (TAPP) procedure is the easier technique to master. The *totally extraperitoneal* (TEP) procedure was initially believed to be superior, but recent comparisons have not confirmed the increased complications and recurrences reported in the early TAPP results.[2]

EMERGENCY INGUINAL HERNIA REPAIR

Emergency repair is necessary when strangulation is present or imminent. The first priority is release of the strangulated contents and resection if the contents are infarcted (see Chapter 23 and Figure 23.2). The hernia is then repaired by one of the methods described below. In the presence of strangulated bowel, the operation field is inevitably contaminated with bacteria and there is still surgical debate as to whether mesh is better avoided in these circumstances.

RECURRENT INGUINAL HERNIA REPAIR

The dissection in the inguinal canal may be straightforward or very difficult because of the presence of dense scar tissue. Occasionally, the cord is lying very superficially and can be damaged even before this stage is reached. Cord damage is much more likely in a recurrent repair and the possible need for an orchidectomy, or late loss of the testis, should be discussed with the patient preoperatively. The pre-peritoneal approach – either open or laparoscopic – should be considered, as it avoids the scarring within the inguinal canal. Increasingly, though, the original repair has been performed laparoscopically and therefore to avoid scarring the second operation should probably be through the inguinal canal.

A recurrent hernia occasionally occurs through the prevascular space in front of the femoral artery and vein. Safe dissection may require division of the medial end of the inguinal ligament. It is reattached after the sac has been dissected off the vessels and the peritoneum closed.

Open adult inguinal herniotomy

Open adult inguinal herniotomy is usually merely the first stage of a herniorrhaphy. General, regional or local infiltrative anaesthesia is suitable.

The classic incision is made 2.5 cm above and parallel to the medial three-fifths of the inguinal ligament, but a more horizontally placed skin-crease incision will produce a more acceptable scar. One or more superficial epigastric veins cross the line of incision in the subcutaneous fat and require ligation or diathermy coagulation. The incision is deepened until the aponeurosis of external oblique is exposed. The superficial inguinal ring, through which the cord emerges, is identified. The external oblique aponeurosis is divided in line with its fibres, the incision being placed so that it opens into the upper part of the superficial ring (Figure 25.2a). Forceps are applied to the two cut edges and both leaves elevated. The ilio-inguinal nerve can usually be identified and preserved.

The cord, with its coverings, is lifted up from the medial part of the incision and spread out on the surgeon's finger (Figure 25.2b). The coverings are incised longitudinally and separated off the underlying cord. The sac appears as a pearly-white structure, lying anterior to the main components of the cord. It is most easily identified at the fundus, the crescentic border of which lies transversely across the cord, and is picked up and held in artery forceps (Figure 25.2c). The cord must also be inspected in this way when a direct hernia is repaired, as an additional indirect sac is not

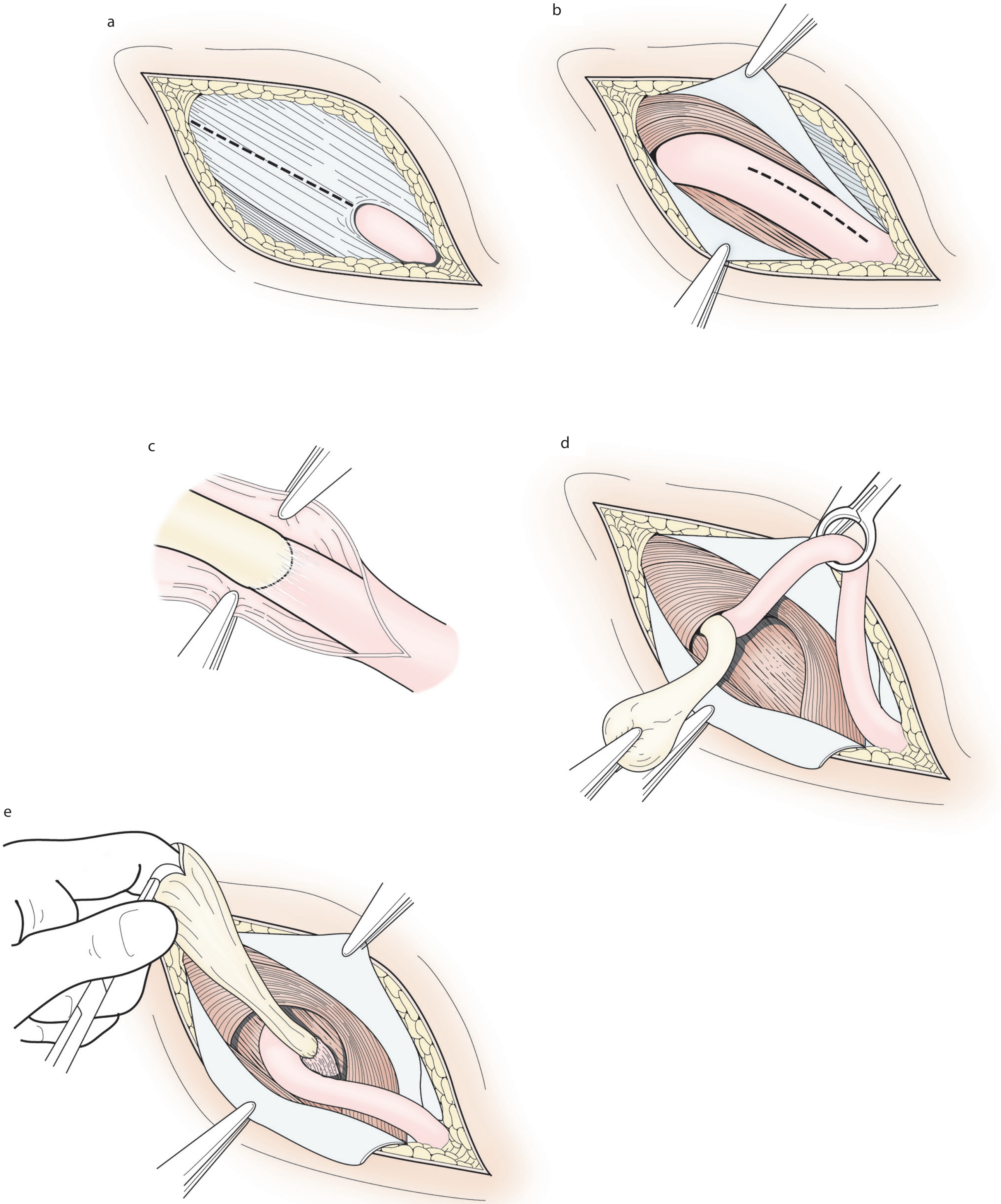

Figure 25.2 *Adult right herniotomy. (a) The external oblique aponeurosis is divided. (b) The cord with its coverings is delivered up into the medial part of the incision and the coverings divided longitudinally. (c) Artery forceps have been placed on the divided edges of the cord coverings, which have been separated off the cord. The sac is now visible as a pale structure with a crescentic distal edge lying on the cord structures. (d) Artery forceps on the sac and a Lane's forceps around the vas and testicular vessels allow counter-traction to display the plane for dissection. (e) The sac has been opened to check it is empty before transfixion just above its neck.*

infrequently present. The cord structures are then separated from the sac as far as the neck. Sharp dissection with scissors or diathermy, and blunt stripping with a swab, are acceptable techniques. Care must be taken in all methods to avoid injury to the testicular vessels. The vas is also vulnerable to inadvertent division as it often lies separate from the other cord structures, closely applied to the sac. A Lane's forceps around the cord structures is useful both to safeguard them and to provide counter-traction (Figure 25.2d). Dissection continues until the neck of the sac is exposed.

The sac should then be opened, some distance from the neck, to ensure that it is empty. A finger inside the sac can also be used to feel for an excessively thick medial or lateral wall, which could represent an additional sliding component to the hernia. Tension on the sac then allows a transfixion suture to be placed immediately above the neck (Figure 25.2e). Care must be taken to ensure that underlying bowel is not transfixed. The sac is then amputated 1 cm distal to the ligature and, if the dissection has been adequate, it will retract inside the deep ring. If no repair is deemed necessary, the external oblique is closed and the skin sutured.

The alternative approach to the cord for a simple herniotomy is through an incision in the external oblique, which leaves the superficial ring intact. Access is more limited, but the advantage is less disturbance to the anatomy and function of the inguinal canal. This approach is particularly favoured by paediatric surgeons, and is described below.

Scrotal hernia

In a scrotal hernia, where the fundus of the sac may not come easily into view, there is no contraindication to leaving the distal part of the sac *in situ*. The sac is separated for a short distance from the cord structures, and is then divided transversely. The distal part is dropped back, while the proximal part is cleared up to its neck and removed in the usual fashion. This method obviates the dissection required to deliver the sac from the depths of the scrotum, and greatly reduces the risk of postoperative haematoma.

Sliding hernia

A sliding hernia contains tissue that lies outside the peritoneal sac. This may be extraperitoneal fat, sigmoid colon, caecum or bladder. If the associated sac is small and the situation is fairly obvious, there is no necessity to excise the sac and the abdominal contents are merely replaced before repair of the hernial defect. On other occasions, the bowel or bladder forms one wall at the neck of a large sac and is in danger of injury if not recognised. Only a partial sac excision is then possible, the remaining extraperitoneal tissue being simply replaced into the abdominal cavity before the posterior wall repair. However, it is sometimes possible to release colon adherent to one side of the neck from within the sac. It can then be

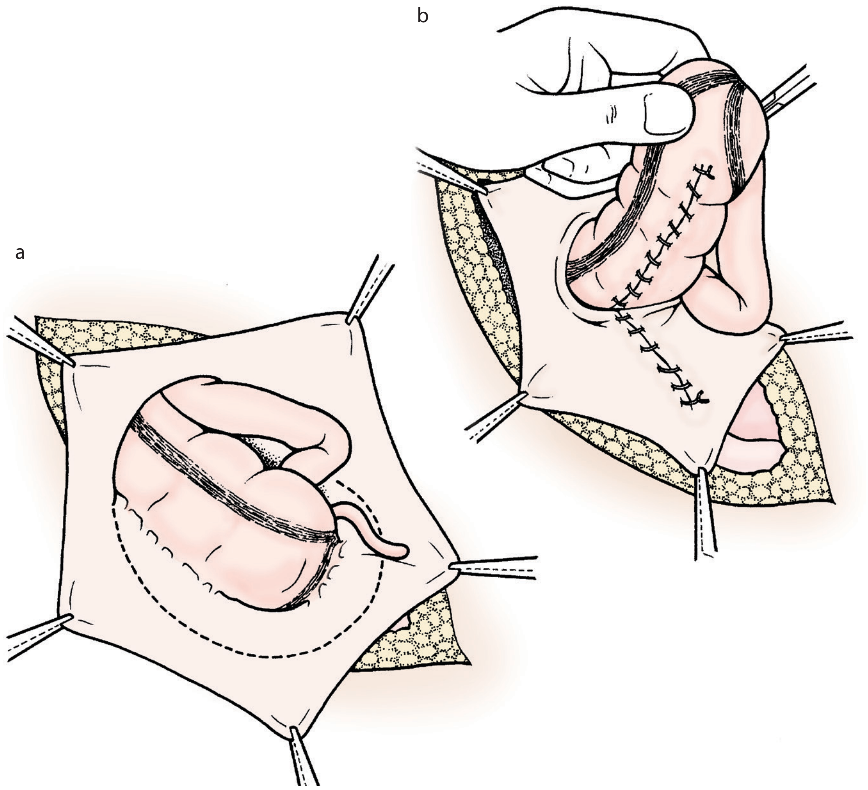

Figure 25.3 *An option in a sliding hernia. (a) The line of incision in the peritoneum of the posterior wall of the sac. (b) Caecum peritonealised posteriorly and the defect in the sac sutured.*

replaced within the peritoneal cavity and the sac transfixed at its neck. A more elaborate manoeuvre is shown in Figure 25.3, but most surgeons would consider this unnecessary.

Direct hernia

A direct inguinal hernia seldom requires a herniotomy, as the herniated tissue is often only extraperitoneal fat or bladder without a peritoneal sac. Any peritoneal sac that is present is usually only a wide-necked bulge, which can be left unopened. The method of closure of the posterior wall defect in the inguinal canal is dictated by the type of repair to be undertaken.

Inguinal herniorrhaphy

Surgery to repair an inguinal hernia through the inguinal canal commences as the herniotomy operation described above followed by one of the techniques described below.

MESH REPAIR

A mesh repair is simple to perform and the recurrence rates are low. A sheet of mesh is used to support the whole posterior wall of the canal. Mesh plugs are used by some surgeons to occlude small direct defects or narrow a stretched deep ring. Mesh repairs are tension free and result in less early postoperative pain than other open repairs. Mesh infection, which occurs in around 1 per cent of patients, is a serious complication, which usually requires the mesh to be removed. Routine antibiotic prophylaxis is recommended (see Appendix II). The cost of the mesh may be unacceptable for surgeons working within very limited healthcare budgets, but mosquito netting has been used as a low-cost alternative.[3]

Surgical technique

An indirect herniotomy is completed. A direct sac does not need to be excised or opened and, as the mesh will support the whole posterior wall of the inguinal canal, a formal repair of the fascial defect of a direct hernia is considered unnecessary by many surgeons. Others prefer to make a circumferential incision through the stretched fascia at the edge of the defect and close it with a continuous suture. An absorbable suture is satisfactory, as it will be supported ultimately by the mesh. This step certainly makes placement of the mesh easier if the hernia is large, but may increase postoperative pain; it certainly should be avoided if the defect is wide and tension would ensue from this suture. The whole posterior wall of the inguinal canal must then be exposed. Cremasteric muscle fibres running from the deep ring to the cord are divided, and cremasteric vessels lying along the floor of the canal are ligated and divided. The genital branch of the genitofemoral nerve runs alongside the cremasteric vessels, and surgical opinion varies as to the advisability of preserving or dividing this. The ilioinguinal nerve is vulnerable in all repairs and if caught up in the sutures, late pain may be problematic. The nerve can usually be safeguarded, but complete division is without adverse effects.[4] A polypropylene mesh is cut to cover the whole posterior wall of the canal and extend around the deep ring. There is no tension, and sutures are only used to prevent early displacement before tissue ingrowth secures it in position. A Prolene™ running suture holds the lower edge of the mesh to the inguinal ligament. An additional four to five sutures will prevent rolling of the edges of the mesh and can hold the cut edges of the mesh together again around the cord at the deep ring (Figure 25.4). Sutures should not be placed through the periosteum of the pubic tubercle. Previously, when repairs commonly included this stitch, it was a frequent cause of late groin pain.

BASSINI REPAIR

The original repair developed by Bassini during the 1880s emphasised the importance of the reconstitution of the transversalis fascial layer of the posterior wall of the inguinal canal. However, the modified operations that bore his name had a high recurrence rate.[5,6] Often, the repair was performed too superficially and failed to repair the transversalis fascia, the sutures merely apposing the muscle fibres of internal oblique to the inguinal ligament. Tension was recognised as a potential problem when a true transversalis fascia repair was performed. Vertical release of the anterior rectus sheath, the *Tanner slide*, was a useful later modification, which reduced tension on the repair (Figure 25.5).

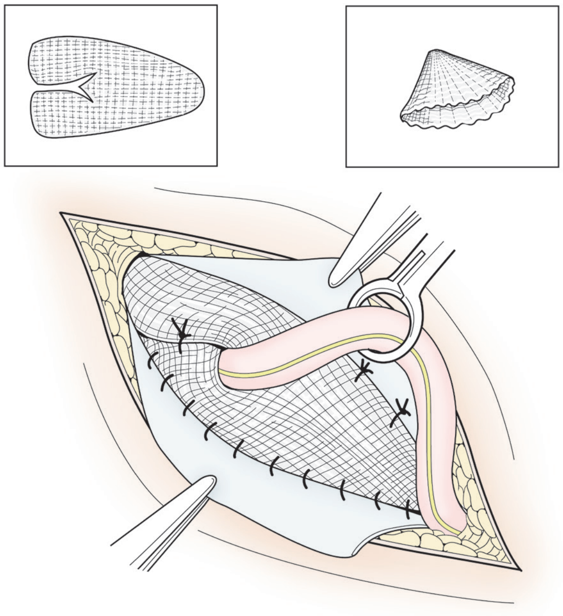

Figure 25.4 *A right mesh herniorrhaphy. The mesh is cut to the shape of the posterior wall. It should extend medially beyond the pubic tubercle and laterally beyond the deep ring. A continuous suture attaches the mesh to the inguinal ligament. A few additional sutures prevent rolling up of the edges. The insets show a mesh plug and the shape of mesh required to cover the whole posterior wall. Note the slit to allow the mesh to be laid around the deep ring.*

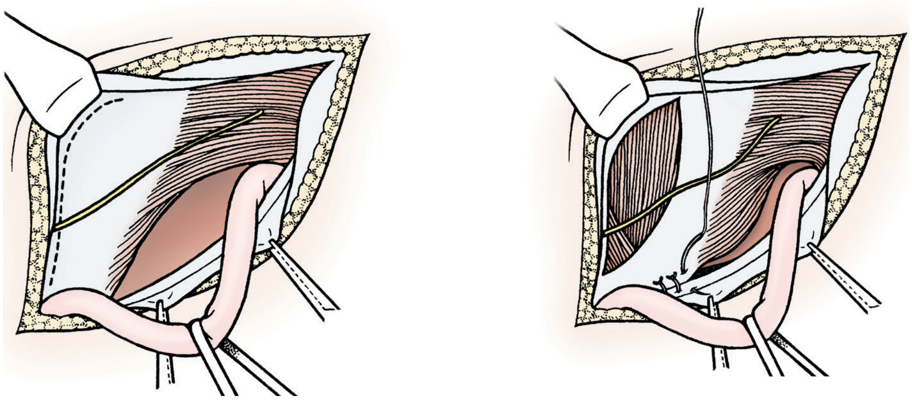

Figure 25.5 *A left herniorrhaphy in which a Tanner slide is illustrated. A vertical incision has been made in the anterior rectus sheath to reduce tension in a Bassini repair.*

SHOULDICE REPAIR

This refinement of Bassini's posterior wall repair can offer recurrence rates of under 1 per cent.[7] The cremasteric muscle is cleared off the posterior wall, which is then divided throughout its length before reconstitution with a four-layer overlapping technique. The pre-peritoneal fat is displaced posteriorly and the first layer of the repair is commenced medially, approximating the lower cut edge of the transversalis fascia to the deep surface of the fascia of the upper flap. When the internal ring is reached, the last stitch incorporates the stump of the cremasteric muscle to form a new snug internal ring. Suturing is then reversed and the second layer unites the upper cut edge of the transversalis fascia to the inguinal ligament. The third layer approximates the internal oblique muscle to the deep surface of the lower flap of external oblique, close to the inguinal ligament. The final fourth layer approximates further muscle, again to external oblique, a portion of which is now incorporated into the posterior wall. It is therefore important that the initial incision in external oblique is not placed too low or its final closure, superficial to the cord, will prove problematic. It is a difficult repair to perform well and simpler modifications, in which the third and fourth layers are omitted, have not consistently been associated with these low recurrence rates.

NYLON DARN REPAIR

After the posterior wall has been cleared and any direct defect closed, an alternative to a mesh is a reinforcement of the posterior wall with a monofilament nylon darn. The darn should be loosely laid in the muscle and must not draw the tissue together. It must cover the whole posterior wall, and no significant gaps should be left between fibres otherwise small narrow-necked direct herniae may occur between strands of the darn. Recurrence rates overall are high except for those performed by surgeons whose darns are so dense that they resemble a mesh. The technique has been generally abandoned in favour of mesh repairs.

OVERVIEW

All of the above repairs are suitable for either a general or a local anaesthetic technique. Eric Farquharson's interest in ambulatory hernia surgery was revolutionary at a time when patients were confined to bed for between 2 and 4 weeks after hernia repair.[8] Same-day discharge during the 1950s was only practical after techniques performed with local anaesthesia, but it is now equally appropriate after general anaesthesia.

Hernia repair under local anaesthesia

Although always an option, a repair under local anaesthesia is particularly well tolerated in the elderly and avoids the risks associated with a general anaesthetic. Diathermy and blunt dissection are more likely to cause pain than sharp scissor dissection, and care should be taken to avoid traction on the cord or peritoneum, which can provoke bradycardia and arrhythmias. The incision should always be of adequate length to avoid excessive retraction, and gentleness is essential.

One of the many satisfactory techniques is to inject 5–10 ml of 0.5 per cent lidocaine with adrenaline (prepared by diluting the standard 1 per cent solution with equal volumes of normal saline) immediately under the intended skin incision, and a further 5 ml into the deeper subcutaneous fat at the lateral end. Anaesthesia occurs almost immediately. The skin incision is made, but only at the lateral end is it deepened to the external oblique, where a further 5 ml of the the local anaesthetic is injected just deep to the aponeurosis. This ensures that the local anaesthetic is in the correct tissue plane and avoids the reported unintentional femoral nerve block. The rest of the wound is then extended down to external oblique. Small nerves run alongside the veins, which have to be ligated in the subcutaneous fat, and before clamping these a further 1 ml of local anaesthetic may be required. The external oblique is then opened and the operation continued in the normal manner. The peritoneum is sensitive, and a few millilitres of anaesthetic should be injected at the neck of the sac before transfixion. Further local anaesthesia is also often required around the cremasteric vessels. Bupivacaine can be mixed with lidocaine for postoperative pain relief or injected separately towards the end of the operation. When bupivacaine is used on its own, the delay in anaesthetic effect has disadvantages.

Bupivacaine injected during surgery under general anaesthesia provides excellent postoperative analgesia for the ambulatory patient. Effectiveness is improved by injecting the bupivacaine at the start rather than after completion of surgery.

Pre-peritoneal inguinal hernia repair

The pre-peritoneal approach is particularly useful for bilateral herniae, when a double incision can thus be avoided, and for a recurrent hernia after a groin repair where it avoids the necessity of dissection within a scarred inguinal canal. The sac is approached at its neck, where it is ligated and divided. The remainder of the sac can be left *in situ* if it does not deliver easily. A fascial defect can be satisfactorily repaired from within, but this is not always necessary, as any mesh will be in the ideal position between the peritoneum and the muscle wall, against which it is held by intra-abdominal pressure. Some sutures or staples are, however, usually still employed to prevent rolling or displacement of the mesh in the immediate postoperative period. Pre-peritoneal repairs are now more commonly carried out laparoscopically.

OPEN APPROACH

A transverse incision is made two finger-breadths above the pubic tubercle and deepened through the anterior rectus sheath. The rectus muscle is then retracted laterally to expose the inferior epigastric vessels, which are ligated and divided. After division of these vessels it is possible to enter the correct plane on the peritoneum and sweep this off the abdominal wall to deliver the tongue of peritoneum that is entering the hernial orifice. The hernial sac is ligated at its neck, and the mesh is then laid across the defect. It can be easily tethered anteriorly before the peritoneum is allowed to return to its normal position supporting the mesh against the undersurface of the abdominal wall.

LAPAROSCOPIC TOTALLY EXTRAPERITONEAL PROCEDURE

The laparoscopic TEP repair commences with obtaining pre-peritoneal access and creating a space within which to work (see Chapter 13). The anatomy is defined and the immediately visible inferior epigastric vessels are a useful landmark. They are vulnerable during dissection and injury has also occurred to external iliac vessels. The surgeon then works along the roof of the dissection space, freeing the peritoneum and pre-peritoneal fat from the abdominal wall fascia.[9] A direct hernia will separate off the abdominal wall, leaving an area that bulges with gas insufflation. Dissection then proceeds laterally, with the inferior epigastric vessels elevated against the abdominal wall for protection. At the deep ring either the spermatic cord or an indirect sac comes into view. Dissection around the sac allows a wide-necked sac to be inverted, but a narrow scrotal sac can simply be divided. The mesh is delivered and unrolled so that it covers both the inguinal and femoral canals. Most surgeons elect to tether the mesh with sutures or staples.

LAPAROSCOPIC TRANSABDOMINAL PRE-PERITONEAL PROCEDURE

With the laparoscopic TAPP repair, pneumoperitoneum is established with an umbilical camera port and a port in each flank. The peritoneum is then incised in a horizontal line from the anterior superior iliac spine, passing a few centimetres above the neck of the hernia, as far as the medial umbilical ligament. A flap is then raised heading posteriorly from this incision and taking care to lift only a thin layer of peritoneum. This dissection is continued to either side of the hernia neck, and the sac itself is then dissected free from the cord structures and drawn out of the inguinal canal. The vas deferens and gonadal vessels pass posteriorly from the deep ring, and the iliac vessels lie between them. All are potentially vulnerable during dissection and mesh placement.

The mesh is rolled up and introduced through a laparoscopic port, placed in the same position as described in the TEP repair and held in position with staples or sutures. The peritoneal flap is then fixed back in its original position, with either staples or sutures, in order to cover the mesh.

Inguinal herniotomy in a child

Surgery of infantile herniae should not be delayed as the risk of incarceration and subsequent strangulation is high. The risk is highest in babies aged under 6 months and at this age the initial presentation may be with a strangulated hernia. In infants and children an inguinal herniotomy is sufficient and no repair is necessary. The herniotomy can be performed as described above for an adult hernia, but as no repair is to be performed, there is an argument for disturbing the shutter mechanism of the inguinal canal as little as possible and preserving an unscarred superficial ring. Three approaches to the neck of an indirect sac, which do not divide the superficial inguinal ring, are described below. Laparoscopic herniotomy in infancy has not gained general acceptance because of the reported higher risk of recurrence, and the only debatable advantage is the ability to assess the patency of the contralateral processus vaginalis. It does have a role in recurrent inguinal herniae when re-exploration through the scar tissue in the groin can be avoided.

Hydrocoeles are common in infancy and many resolve by spontaneous obliteration of the processus vaginalis. Surgery is therefore normally postponed until the child is 2 years old. Encysted hydrocoeles of the cord are less common and seldom resolve spontaneously. The operation for an infantile hydrocoele is ligation and division of the proximal end of the processus vaginalis, and is thus the same operation as that for an infantile hernia.

THE LOW OPERATION

In this procedure the cord is approached outside the superficial ring. Although this technique can be applied to all ages, it is most suitable in infants younger than 1 year who have a very short canal and there is overlapping of the superficial and deep inguinal rings. A skin crease incision 2–3 cm in length is made just above the pubic tubercle (Figure 25.6a). The incision is deepened through the membranous layer of superficial fascia, which is a significant layer at this age and may cause confusion if it is mistaken for the external oblique. Veins in the fat can be safely coagulated. Once the external oblique aponeurosis is defined, the lower edge of the wound is retracted and the cord identified just outside the superficial ring. If difficulty is encountered, traction and release of the testis will usually help to identify the cord moving in the fat. The cord is then gently delivered into the wound along with its coverings. An artery forceps passed beneath the cord will hold it securely on the surface under light traction. Alternatively, a vascular sling can be passed under the cord, as shown in Figure 25.6b. The coverings are incised longitudinally. These include the cremaster muscle, which is frequently thick and hypertrophied in association with an infantile hernia. Artery forceps are placed on both cut edges and act as retractors to enable the surgeon to enlarge this incision in the correct plane and to separate the cord from its coverings. It is then possible to lift the cord free and pass another artery forceps under the isolated cord and allow the coverings of the cord to fall back into the wound. It is important to have haemostasis assured before allowing this tissue to retract.

The sac is then identified. A short sac is lifted in its entirety off the vas and vessels. A long scrotal sac is separated from the vas and vessels sufficiently to allow transection. The distal sac is left *in situ* and the dissection restricted to the proximal portion of the sac. Isolation of an *infantile hernial sac* may be extremely difficult as it is often wide and gossamer thin, with the cord structures spread over the surface. Delicate unhurried dissection with fine instruments and good light is essential. Ideally, the cord structures are teased off the unopened sac, which can be held between finger and thumb. However, this is not always possible and the surgeon may find that the sac has been entered and that the dissection has to be completed from within. In this situation, two-thirds of the diameter of the sac is free of cord structures and is divided transversely, with fine artery forceps being applied to the proximal cut edge. The remaining third has to be dissected off the underlying cord structures. This is difficult because of the extreme delicacy of the thin-walled sac (Figure 25.6c). Once the circumferential division is complete, the proximal sac is ready for dissection off the cord.

A single artery forceps can now be placed on the isolated proximal sac and gently retracted away from the cord structures. An Allis forceps around the vas and vessels provides useful counter-traction. Fine areolar strands are divided and the sac separated from the cord as far proximally as is possible. The dissection can be carried up to the neck of the sac without opening the short inguinal canal of an infant or very young child. When the sac is transfixed, divided and released it will retract through the canal to lie inside the deep ring. Great care must be taken to avoid inclusion of vas or vessels in the transfixion stitch.

The identification and isolation of a *narrow persistent processus vaginalis* is usually straightforward. It appears as a pale, thin-walled, translucent tube of 1–2 mm diameter. The testicular vessels appear blue and the vas, although of similar diameter, can be identified as a palpable cord. The processus is picked up and divided. Hydrocoele fluid empties from the distal cut end. In the less common encysted hydrocoele of the cord it is preferable to follow the distal cut end to open the cystic swelling, but in the more common hydrocoeles around the testes the distal end is simply dropped back into the

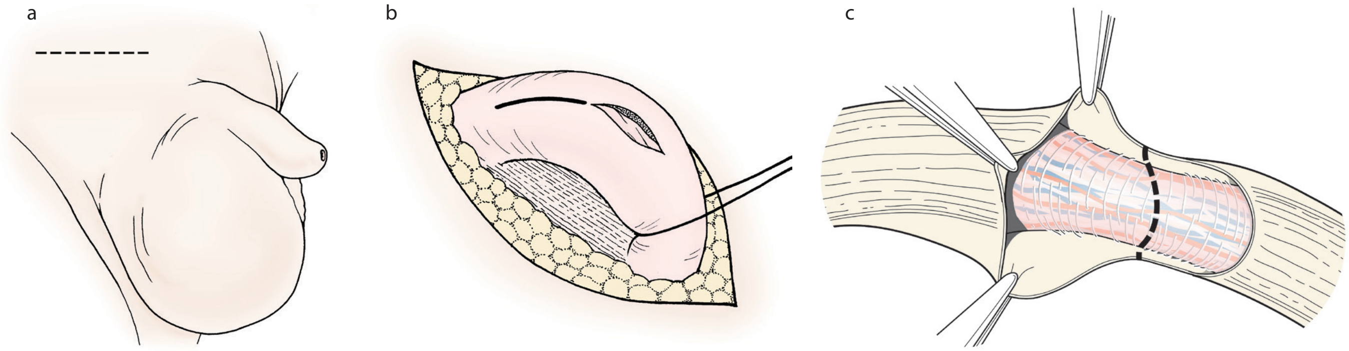

Figure 25.6 *A right infantile herniotomy. (a) A transverse incision above the pubic tubercle. (b) The cord and coverings are identified outside the superficial ring and delivered up into the wound. The coverings are incised and lifted off the cord structures. (c) A thin, wide-necked sac may have to be dissected from within. The vas and vessels are visible through the undivided segment of sac, which must be separated from them very gently as the remainder of the circumference of the sac is divided along the dotted line.*

wound and left *in situ*. The proximal end of the patent processus is transfixed after the same dissection as for an infantile hernia.

THE HIGH OPERATION

In this procedure the cord is approached within the inguinal canal through an incision in external oblique. A skin crease incision is made over the deep inguinal ring and the external oblique is opened in the same line. This incision is only 1–2 cm in length and is not extended to the superficial ring. The internal oblique is then split at its junction with the cremaster muscle. The cremaster muscle and the internal spermatic fascia are then opened to expose the sac and the structures of the cord, which are lifted forwards into the wound. Thereafter, the dissection is similar to that in the low operation.

THE PRE-PERITONEAL OPERATION

In this approach the skin incision can still be placed inconspicuously, as for the low operation, but must be longer. After incision through Scarpa's fascia the upper flap is raised off the external oblique for 2–3 cm. A transverse muscle-splitting incision is then made through external oblique, internal oblique and transversus. The neck of the sac is then approached from above, by dissection deep to the abdominal wall muscles. The transversalis fascia must be divided to ligate the sac flush with the parietal peritoneum. It can either be divided before the dissection and lifted with the rest of the abdominal wall, or be left to support the thin peritoneum during dissection and divided only once the sac has been identified in a more superficial plane.

INGUINAL HERNIOTOMY IN THE FEMALE CHILD

In the young girl or baby, an ovary or the fimbrial end of a Fallopian tube can prolapse into the sac. The ovary is frequently irreducible and may be mistaken preoperatively for a lymph node. Inguinal herniae are common in androgen insensitivity (formerly testicular feminisation) syndrome, and sex chromosomes should be checked in female children with bilateral irreducible inguinal herniae containing gonads. The operation is similar to that in the male, but the sac is easier to dissect in the absence of fine cord vessels that need to be safeguarded. Care must still be taken to avoid injury to a herniated ovary or tube, which must be returned into the peritoneal cavity.

INCARCERATED INFANTILE INGUINAL HERNIAE

An incarcerated hernia can usually be reduced by sedation of the baby, followed by gentle manual reduction. The contents are most commonly loops of small bowel. In girls, attempts to reduce an incarcerated ovary should be avoided, as it may lead to torsion. If non-operative reduction is achieved, surgery should ideally be delayed for 48–72 hours to allow the oedema to settle. Further delay risks recurrent strangulation. A pre-peritoneal approach may be preferable when there has been a recent episode of strangulation, as it avoids the need to dissect a friable oedematous sac. Emergency herniotomy is essential if reduction is not achieved. At operation, the reduction is usually straightforward and a simple herniotomy is all that is required. The infantile gonad is more vulnerable to strangulation than the bowel and subsequent testicular infarction is not uncommon. Infarcted bowel requiring resection is rare. When bowel cannot be reduced at operation and viability is in doubt, it is very difficult to release and repair the neck of the peritoneal sac in the same fashion as in an adult. An additional separate laparotomy approach may be the safer option. If a resection and anastomosis is indicated, it can also be performed more satisfactorily by this approach, as it is difficult to return an anastomosis through the small deep ring.

FEMORAL HERNIAE

Femoral herniae occur almost exclusively in adult women because the femoral ring is wider. They are rare in men and in children. However, in both sexes and at all ages, femoral herniae are less common than inguinal herniae.

Anatomy

The *femoral canal* is the medial of the three compartments of the femoral sheath, which is formed by a prolongation into the thigh of the fascia transversalis and the fascia iliacus, which line, respectively, the anterior and posterior abdominal walls. The lateral compartment of the sheath contains the femoral artery and the intermediate one the femoral vein. The internal orifice of the femoral canal is the *femoral ring*. It is relatively rigid as it is bounded anteriorly by the inguinal ligament, posteriorly by the pectineal line of the pubis and the fascia overlying pectineus and medially by the free edge of the lacunar ligament. Laterally, it is bounded by the femoral vein. The ring is normally occluded by a pad of fat containing lymphatic tissue.

The hernia descends through the femoral canal and then turns forwards through the saphenous opening in the fascia. The cribriform fascia, which covers the opening, is thinned out in front of it. The hernia may then turn upwards and laterally to overlie the inguinal canal. The femoral ring is narrow and many herniae are irreducible from the time of presentation. The potential for strangulation is high and surgery should be advised.

THE LOW OPERATION

In this procedure the incision is made 1 cm below and parallel to the medial portion of the inguinal ligament. A lipoma-like swelling is immediately encountered covered with thin fascia (Figure 25.7). Dissection around this leads to the femoral canal, and confirms that it is a femoral hernia and not a lipoma. The actual sac is often surprisingly small and is deeply

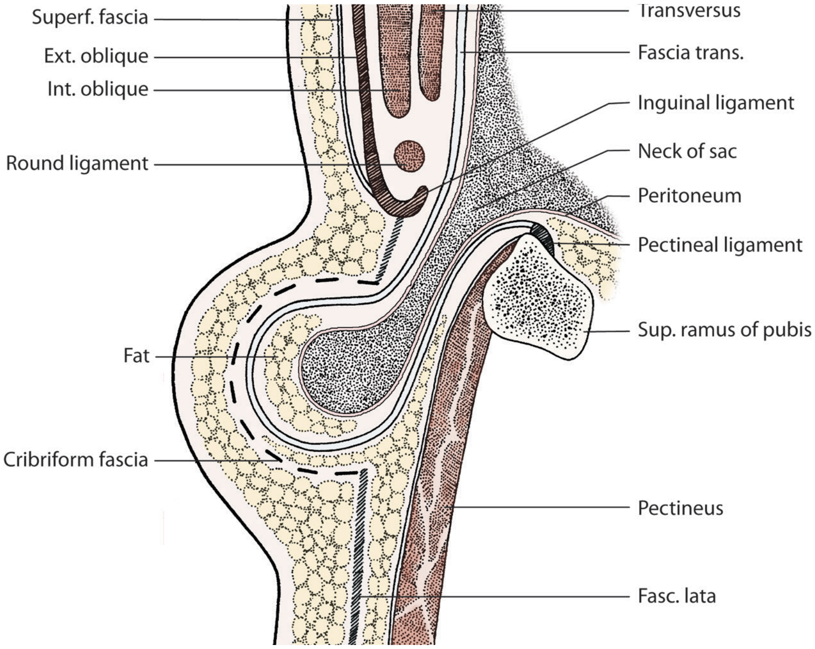

Figure 25.7 *The anatomy of a femoral hernia. The fat beneath the thin cribriform fascia presents at operation as a lipoma-like swelling.*

embedded in the condensed fatty tissue contained within the stretched cribriform fascia. The sac is isolated by incision into these tissues. It is freed to its neck, then opened at the fundus and any viable contents returned to the abdominal cavity. Omentum is often adherent to the sac and requires to be separated. Alternatively, if it is free at the neck but adherent at the fundus, the adherent portion can be removed with the sac. When the neck of the sac is constricted by a tight femoral ring, it can be released by an incision medially into the lacunar ligament, but an aberrant vessel on its surface will occasionally cause troublesome bleeding. Temporary division of the medial end of the inguinal ligament is occasionally justified in very difficult circumstances. The neck of the sac is freed from the margins of the canal and then transfixed and ligated as high as possible so that it retracts above the canal.

The femoral ring palpated from below feels triangular, with semi-rigid anterior and posterior walls that meet at a very short medial wall. The femoral vein forms the soft lateral wall of the triangle. Complete closure of the femoral ring itself with sutures is seldom possible, as even if the anterior and posterior walls can be pulled into apposition, the femoral vein will be compressed and partially occluded. A compromise is the placement of two to four sutures across the ring from the fascia over pectineus muscle posteriorly to the inguinal ligament anteriorly. A **J**-shaped needle makes the placement of these sutures easier, and the femoral vein is protected throughout by a finger placed over it. The sutures are all inserted before any are tied. The most medial suture is tied first and ligation is continued laterally until it is judged that tying the next suture would compress the femoral vein (Figure 25.8). Any remaining untied sutures are then removed. A small plug of mesh inserted before these sutures are placed will give extra security, but recurrence of femoral herniae is surprisingly uncommon.

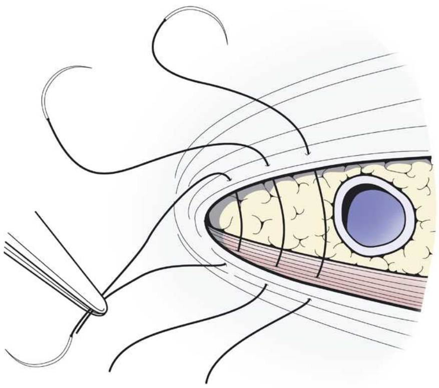

Figure 25.8 *Left femoral hernia repair. Sutures placed between the inguinal ligament and the fascia overlying the pectineus muscle close to its attachment to the pubic bone can be used to obliterate the femoral ring.*

Although viable bowel can be released and returned to the abdomen and infarcted omentum can be excised, this approach is probably unsuitable for a strangulated case where infarcted bowel may be encountered; even if it is possible to draw healthy tissue down for the resection, it is unlikely that the anastomosis can be returned through the femoral ring and an additional higher incision becomes necessary.

THE HIGH OPERATION

There are several operations described that all involve approaching the neck of the sac from above, through the preperitoneal plane. The main advantage is better access to herniated bowel for assessment of viability and, if required, resection. The two older classical approaches both have major disadvantages and have been abandoned:

- *The Lotheisen approach*, through the conjoint tendon, inevitably weakened the inguinal canal.
- *The McEvedy approach*, through a vertical incision in the anterior rectus sheath near its lateral border, was via a vertical skin incision across the groin crease, with subsequent troublesome wound healing.

The present standard high operation is a pre-peritoneal approach similar to that described above for an inguinal hernia. It is suitable for an open or a laparoscopic operation, gives excellent access for a mesh closure of the femoral canal and is now the method favoured by many surgeons for all femoral herniae. In a strangulated case the peritoneum can be easily opened to check viability and resect if necessary. Only very occasionally does it prove impossible to draw infarcted bowel up into the wound, necessitating an additional lower incision to remove the gangrenous loop from below.

INGUINAL LYMPH NODES

Anatomy

The *superficial inguinal lymph nodes* form a horizontal group below the inguinal ligament and a vertical group along the upper 5–8 cm of the great (long) saphenous vein. They drain the superficial tissues of the lower abdominal wall, lower limb and perineum. The *deep inguinal lymph nodes*, three or four in number, lie along the proximal end of the femoral vein and in the femoral canal; they drain the deep tissues of the lower limb. The superficial and deep nodes drain into the external iliac nodes.

EXCISION BIOPSY

An excision biopsy of an inguinal node is undertaken for histological diagnosis. An enlarged node may be selected or a *sentinel node* identification technique may be employed, as described in the section on malignant melanomas in Chapter 2.

INGUINAL NODE DISSECTION

This is undertaken as a potentially curative operation when malignant spread is believed to be only to these nodes. It can also be used as a palliative procedure to gain local control of a malignancy. It must be remembered in both scenarios that the division between inguinal and external iliac nodes, which are in direct continuity, is artificial. Malignant melanoma and squamous cell carcinoma of the anus, vulva and penis are tumours for which this operation is most likely to be considered. There is significant morbidity following radical inguinal node excision. Complications include skin breakdown because of poor blood supply to skin flaps, subcuticular lymph collection despite postoperative vacuum drainage, and late lymphatic oedema of the lower limb.

Operative procedure

The skin incision may be oblique, vertical or curved (Figure 25.9). Skin flaps must then be elevated so that all but the most superficial subcutaneous fat can be excised from the groin. The upper limit of this excision is 5 cm above the inguinal ligament, where a transverse incision is made through the fat to expose the external oblique. All fatty, fascial and nodal tissue distal to this incision is then stripped off the external oblique aponeurosis down to the level of the inguinal ligament, securing superficial vessels crossing the field. Distally, a skin flap is raised so that the long saphenous vein is exposed. If the saphenous vein is to be removed with the nodes, it is ligated and divided between ligatures at least 10 cm below the inguinal ligament. Its stump is then turned upwards together with all the surrounding fat and lymph nodes. Some surgeons preserve the vein in an attempt to reduce lower limb oedema, but the subcutaneous tissue must still be divided at the same level to remove all the fat and lymph nodes. The partially separated tissue is then stripped from the inguinal ligament from the lateral to the medial side. If the long saphenous vein has been divided, it is divided again at its junction with the femoral vein and small arteries arising from the femoral artery are also divided. The femoral vessels are exposed and all fatty and nodal tissue cleared away from the medial side of the femoral vein and from the femoral canal. Haemostasis is secured and the skin flaps closed over vacuum drains through which lymphatic drainage is usually substantial and may persist for some weeks. The operation may be combined with a further dissection of the iliac nodes, as discussed in Chapter 16.

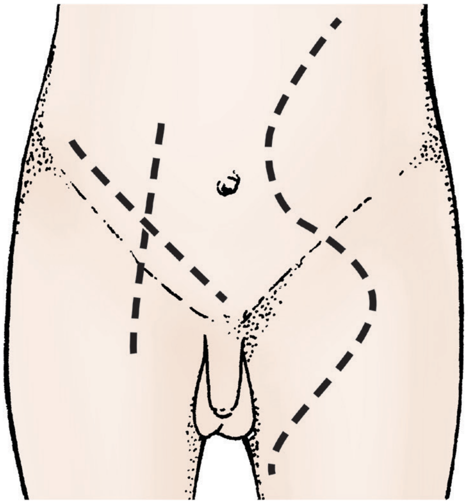

Figure 25.9 *Incisions for a radical inguinal node dissection.*

SURGERY OF THE TESTIS, SCROTUM AND CORD

This surgery is mainly within the remit of the urologist or paediatric surgeon, but some overlap between specialists is inevitable. In children, the surgery is dominated by the treatment of testicular maldescent. A truly *undescended testis* lies in the path of descent: in the abdomen, inguinal canal or scrotal neck. An *ectopic testis* has left the normal path of descent and is most commonly found in the superficial inguinal pouch, overlying the inguinal canal, deep to Scarpa's fascia. A testis that has not descended to the scrotum rarely has satisfactory spermatogenesis, and histological deterioration can be demonstrated from early childhood. If the baby is full term, it is unlikely that spontaneous descent will occur after 2 months of age, and surgical correction should be undertaken as soon as it is reasonable to do so. The surgeon should, however, be aware that the incidence of testicular atrophy after an orchidopexy may be higher when the operation is carried out at a younger age. The age for operation will also depend on the local provision for paediatric anaesthesia, but where facilities are good, the operation is often undertaken before 2 years of age. By 1 year of age all but 0.9 per cent of testes are in the scrotum, but after that time the cremasteric reflex develops and care must be taken to distinguish a normally descended, but retractile, testis, for which no treatment is indicated.

Orchidopexy

Orchidopexy is the operation to mobilise a maldescended testis and bring it into the scrotum. A groin exploration is suitable when the testis is palpable. The incision is made over the inguinal canal and deepened to expose the external oblique. Retraction allows identification of the external ring. An ectopic testis, or one in the scrotal neck, can be delivered into the wound and held between finger and thumb. This may also be possible at this stage for a testis that can be milked along the inguinal canal and held as it emerges from the superficial ring. However, a small high testis, lying near the deep ring, may only become apparent once the canal is opened. A gubernacular attachment down to the scrotum may be an obvious band, and the testis must be released from this. The external oblique is divided as for a hernia repair, but the incision must be carried 1–2 cm lateral to the deep ring to allow sufficient access for the later dissection. The incision can end medially lateral to the external ring, as shown in Figure 25.10, but division often allows better access. Gentle traction on the testis demonstrates the fibres of cremaster,

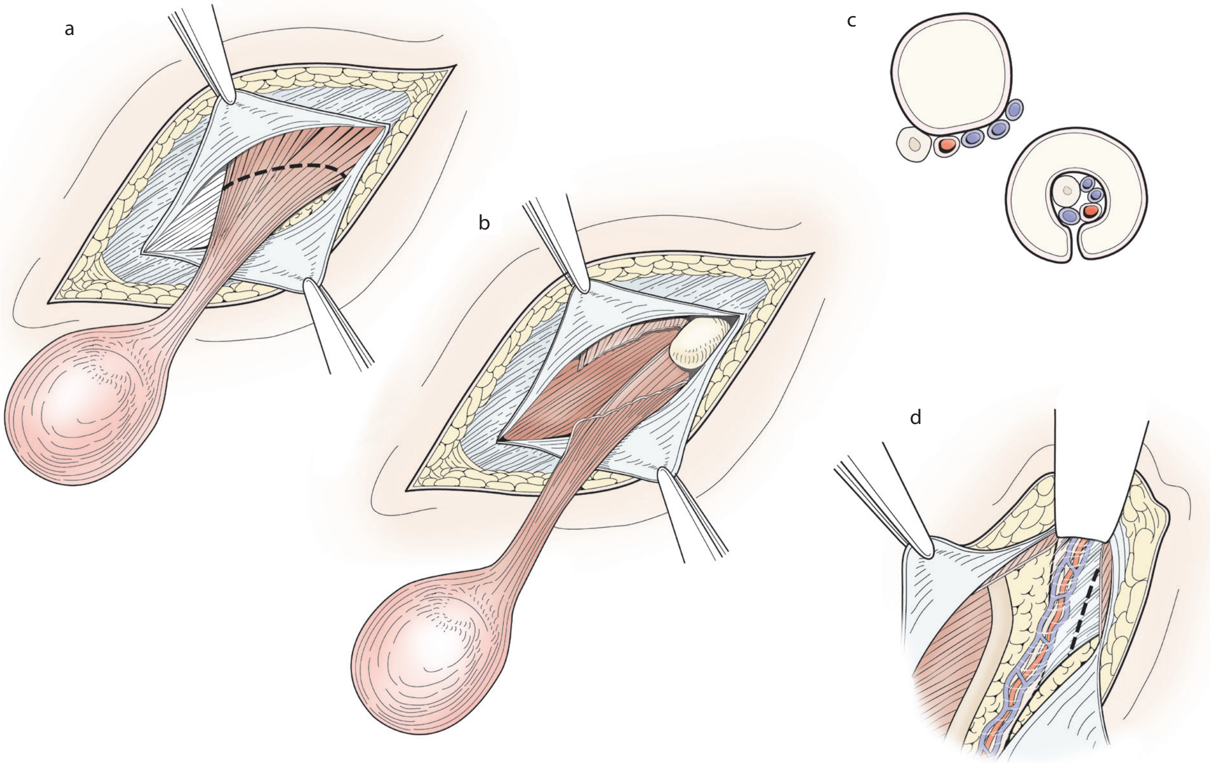

Figure 25.10 *Left orchidopexy. (a) The external oblique is incised. The testis is retracted anteriorly and the cremasteric fibres divided. (b) The small knuckle of peritoneum on the surface of the cord at the deep inguinal ring must be lifted and dissected off the cord. (c) The sac is commonly thin walled and wide necked. The cord structures may be spread out over its surface or even enclosed within a peritoneal fold. (d) Retraction of the deep ring displays the avascular lateral bands to the testicular vessels, which must be released. Insufficient lateral release of the external oblique will restrict access. The vas can be seen to be turning medially away from the vessels.*

which are holding it, and release of these usually gives significant extra length (Figure 25.10a). The testis is now free except for its attachments through the internal ring – the vas, testicular vessels and a hernial sac, if present.

The peritoneum must now be dissected off the cord. On occasion, it is only a small thick-walled knuckle lying on the anterior surface of the cord. Artery forceps are applied to this knuckle of peritoneum and as it is lifted forwards the plane is developed behind it (Figure 25.10b). This plane is essential for the final dissection behind the deep ring. This small sac is then transfixed and excised. Unfortunately, this surgically easy hernia is usually only encountered at orchidopexy in children aged over 4 years, and orchidopexy is now recommended between the ages of 1 and 3 years. A wide, thin-walled sac extending as far as the testis, and often further into the scrotum, is common at this earlier age. The cord structures may be spread out over the sac, as described in the surgery of infantile herniotomy above. Alternatively, the cord appears to be running in the free edge of a testicular mesentery (Figure 25.10c). In both of these situations, delicate dissection to isolate and close the sac, while preserving the gonadal vessels and vas, is essential.

Once the peritoneum, or sac, has been released from the cord, lateral retraction of the deep ring, as the testis is held medially under gentle tension, will demonstrate avascular filmy bands of tissue lateral to the testicular vessels (Figure 25.10d). Division of these strands produces a significant increase in length, and it is then usually possible for the testis to reach a normal position in the scrotum. The limiting factor is almost always insufficient testicular vessel length and therefore the manoeuvre described of division of the inferior epigastric vessels to allow a straighter course for the vas is usually unhelpful.

A subcutaneous tunnel to the scrotal skin is created by the surgeon's finger or a small swab held in forceps; a scrotal skin incision is made and a pocket created between the dartos muscle and the skin (Figure 25.11a). An artery forceps is then passed up through the otherwise intact dartos into the main wound, and is used to draw the testis down (Figure 25.11b). Care must be taken to avoid torsion. The testis is eased through the small hole in the dartos muscle, which will prevent postoperative displacement of the testis out of the scrotum. The scrotal skin is then drawn over the testis and closed with absorbable sutures. One suture can be passed through the capsule of the testis if the dartos is not forming a snug hold on the testis, but should be avoided if possible, as although still unproven, this may be associated with a higher incidence of infertility.[10] A testis that cannot be brought down fully can still be placed in a dartos pouch. The scrotum will pucker upwards, but no damaging traction on the vessels will occur. Improvement in position will continue for at least a year and a further exploration after this time may be beneficial if the testis is still high.

Alternative approaches for orchidopexy are similar to those described for herniotomy in childhood. A high approach through the external oblique directly onto the deep ring, with preservation of the superficial ring, is favoured by some surgeons. The cord is lifted upwards and an incision through the transversalis fascia at the deep ring brings the dissection directly onto the testicular vessels and vas, making separation from the hernial sac easier. After full mobilisation, the testis is guided into the scrotum through the intact superficial inguinal ring. A retroperitoneal approach can similarly be used for the testicular mobilisation and may provide better access when extensive retroperitoneal dissection is required for a high testis.

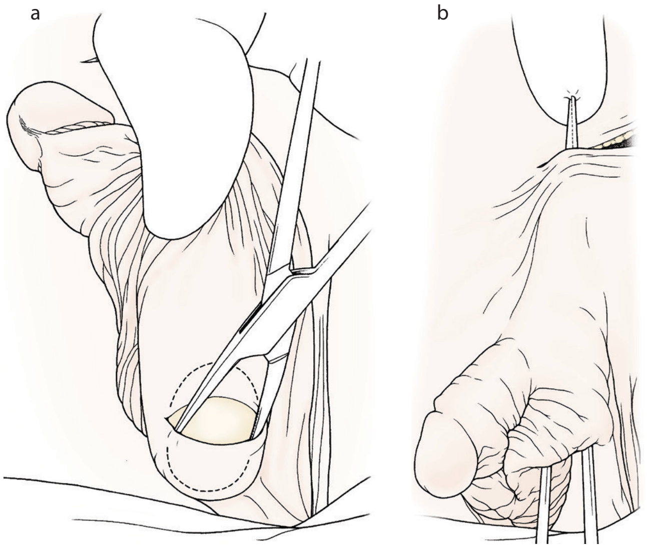

Figure 25.11 *(a) A tunnel has been created from the main wound through to the empty scrotum by the surgeon's finger. A scrotal incision through skin alone is made and a pocket created between the skin and the dartos muscle. (b) An artery forceps is guided up by contact with the surgeon's finger. It passes from the scrotal incision through the dartos muscle and through the scrotum to the main wound. It is then used to draw the testis down into the dartos pouch.*

The intra-abdominal testis

When the testis is impalpable there is often doubt as to whether the testis is absent or intra-abdominal. Groin exploration is contraindicated until there is clarification. An ultrasound scan may be of value, but diagnostic laparoscopy is the most helpful investigation, as it will show testicular vessels and vas entering the deep ring if there is an impalpable atrophic testis in the groin. Alternatively, it will confirm or refute the presence of an intra-abdominal testis. These high testes will seldom reach the scrotum because of short vessels. Preservation of the testicular vessels is not essential to testicular survival as there are anastomotic channels, predominantly with the artery to the vas. Division of testicular vessels above the pelvic brim is a more minor ischaemic insult than division within the inguinal canal. A laparoscopic high division of the testicular vessels can be undertaken at the same time as the diagnostic laparoscopy (*Fowler–Stephens operation*). The testis is left undisturbed, which allows the collateral blood supply to improve, and some weeks later the orchidopexy is performed. Even in expert hands, a Fowler–Stephens operation is still associated with disappointing results. Around 50 per cent rates of testicular atrophy are reported and spermatogenic function may be even worse. General surgeons who operate on children with undescended testes must be aware of the potential benefits of these specialist techniques, so that cases that are not suitable for groin exploration can be identified and referred to the appropriate specialist.

A testis that cannot be brought into the scrotum should be removed after puberty is complete, as the risk of malignant change is significant. In cases of bilateral intra-abdominal testes, gonadal dysgenesis should be considered and karyotype analysis undertaken. Because of the high risk of malignancy in these cases, bilateral orchidectomy may need to be considered.

Torsion

Torsion may occur when there is an abnormal insertion of the tunica vaginalis high up on the cord, allowing the testis to rotate. This abnormality is frequently bilateral and the testes lie horizontally. The twisting of the cord occludes the blood flow. As a testis can only survive around 6 hours of total ischaemia, a suspected torsion warrants urgent scrotal exploration. The diagnosis is mainly clinical but, if torsion is considered unlikely, a normal Doppler ultrasound will be an extra reassurance and may prevent unnecessary surgery. However, it is not a reliable investigation in children given the small testicular volume. It must be remembered, however, that an unnecessary exploration for orchitis, or for idiopathic scrotal oedema, is preferable to a missed diagnosis of torsion. At exploration an infarcted testis, if encountered, is removed and a viable testis untwisted and fixed. The use of absorbable sutures has been associated with recurrent torsion, and fixation at three points of the tunica albuginea to the tunica vaginalis with fine Prolene™ sutures has been recommended. If the first two sutures are inserted but left loose, they can be tied once the testis is replaced within the scrotum; access for the third suture is then not problematic. However, there is still some concern regarding any adverse effects of such sutures on fertility and an alternative method of fixation is to place the testis in a dartos pouch.[11] The opposite testis should also be fixed, as the anatomical variants that predispose to torsion are commonly bilateral. Unfortunately, whether or not the testis can be saved, the ischaemia/reperfusion insult can also be linked to the formation of sperm antibodies, damage to the contralateral testis and decreased fertility. On occasion, repeated episodes of testicular pain are suspected to be due to recurrent partial torsion. An elective bilateral fixation is undertaken. Neonatally and in early childhood a variant of the classical torsion may occur in which the body of a testis, abnormally separate from the epididymis, twists on its own.

At exploration for a suspected torsion, a torted small cyst on the head of the testis (*cyst of Morgagni*) may be the only finding and it is simply excised. If a confident diagnosis can be made preoperatively, an operation can be avoided, but if in doubt it is always better to explore.

Orchidectomy for testicular cancer

Testicular cancer is the commonest cancer in young men. Presentation may be with a palpable testicular lump or an associated hydrocoele. Scrotal ultrasound is very accurate in giving a preoperative diagnosis. Before surgery, blood should be sent for tumour markers and also, if available, consideration should be given to cryopreservation of sperm and a testicular prosthesis offered.

The testis is removed through an inguinal incision, with the testicular vessels and vas ligated at the deep ring, which is then closed. However, first a non-crushing clamp is placed across the cord to protect against tumour emboli while the testis is delivered out of the scrotum for inspection and palpation. This can be particularly helpful when a hydrocoele has hindered preoperative clinical assessment and ultrasound is unavailable. When uncertainty remains, a biopsy for frozen-section histology can be taken, with the testis isolated from the rest of the wound to prevent malignant contamination. If no malignancy is discovered, the clamp is released, haemostasis obtained and the testis reconstituted and returned to the scrotum.

In testicular cancer, consideration should be given to biopsy of the contralateral testis. This is indicated if the ultrasound shows microcalcification, if the contralateral testis is small and soft or if there is a history of maldescent of the contralateral testis. However, these biopsies should only be undertaken if appropriate pathological expertise for their interpretation is available.

When a testicular tumour is unexpectedly discovered during a scrotal operation, the testis can be removed through the scrotal incision. It is not necessary to make a separate inguinal incision in order to excise more of the spermatic cord. Blood should be sent from theatre for tumour markers.

ORCHIDECTOMY FOR BENIGN CONDITIONS

The removal of a testis for *benign* pathology is through the incision from which the testis is most accessible. For a normally placed scrotal organ, an incision in the upper scrotum allows the testis to be delivered out of the wound. In some chronic inflammatory situations, *an epididymectomy* alone may be considered, although it must be remembered that epididymectomy for testicular pain is often ineffective and may make any pain worse.

Vasectomy

Vasectomy for male contraception is one of the most commonly performed surgical procedures in the world. A technique should be chosen that is simple but effective and can be performed on an outpatient basis under local anaesthesia. Using finger manipulation, first one vas then the other is brought to lie in the midline just under the scrotal skin. Access to the vas can be through a single midline scrotal puncture, using the sharp-pointed artery forceps from the 'no-scalpel instrument set', or by a scalpel incision of 1 cm or less in length. There are various techniques to fix and deliver the vas through the wound, including the use of a special ring forceps in the no-scalpel set or, alternatively, an Allis forceps. The next step is to ensure that the vas is cleanly separated from its coverings. This is done by puncturing or incising down onto the vas and reapplying the ring or Allis forceps, allowing the coverings to drop back. Care must be taken never to let go of the vas. The next step is to divide the vas and tie both ends. Most surgeons use Vicryl®, although clips can also be used. Silk ties have been abandoned because of problems with sinus development. Some surgeons leave the testicular ends open as this has been shown to reduce granulomata. However, whether or not the testicular ends are left open, it is important to use a technique that prevents recanalisation. The most effective option is either to separate the ends within different tissue planes or to cauterise the vas lumen. The patient must still be warned that both early and late recanalisation can occur.

Epididymal cysts

These thin-walled translucent cysts, filled with clear fluid, are usually found in the upper part of the epididymis, and lie above the testis. There are commonly multiple tiny cysts, in addition to the one that is palpable, and therefore development of further palpable cysts is likely. Excision is only recommended if a cyst is symptomatic, and should be avoided if future fertility is desired, as surgery carries a risk of obstruction to sperm flow. Excision is undertaken by a scrotal incision over the cyst until its surface is reached. Dissection is then on the surface of the cysts, and an attempt should be made to shell them out intact.

Hydrocoeles

Hydrocoeles in which an underlying testicular malignancy has been excluded can be approached through a scrotal incision. The anterior scrotal skin is held taut over the hydrocoele with one hand and an incision made through skin and dartos. An artery forceps applied to the remaining coverings and the tunica vaginalis before incising into the hydrocoele will enable the sucker to be inserted more easily to drain the fluid. The opening is then enlarged to a size through which the testis can be delivered. The aim of the operation is to leave the testis in such a position that the fluid produced by its tunica albuginea can drain into a different tissue plane. This is mostly simply achieved by several absorbable sutures that plicate the tunica vaginalis so that it lies as a cuff behind the testis (Figure 25.12). The dartos and scrotal skin are then drawn back over the testis and closed. The scrotal incision is satisfactorily closed with a continuous absorbable haemostatic suture in the dartos and a subcuticular absorbable suture in the skin.

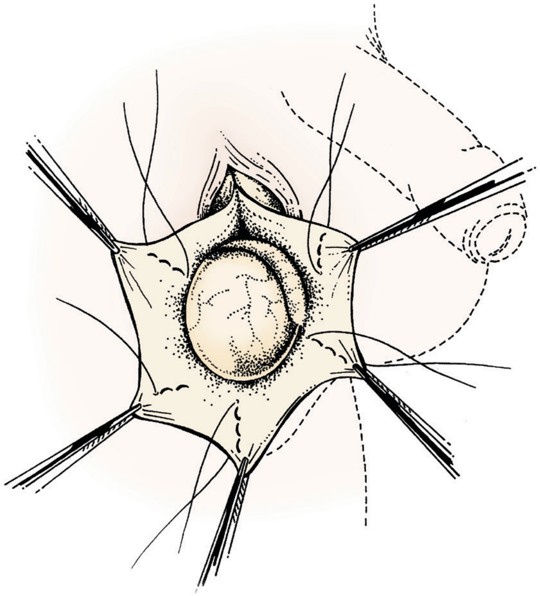

Figure 25.12 *Lord's procedure, in which the tunica vaginalis of a hydrocoele is plicated to prevent recurrence.*

Aspiration of a hydrocoele is usually only a very temporary solution, as the fluid re-collects. Injection of a sclerosant after aspiration can obliterate the space and prevent recurrence. However, this may cause severe pain unless mixed with a short- and a long-acting local anaesthetic agent. A mixture containing 2 ml of a 3 per cent solution of sodium tetradecyl sulphate mixed with 5 ml of 1 per cent lidocaine and 5 ml of 0.25 per cent bupivacaine has proved satisfactory. The procedure can be repeated if necessary.

Varicocoeles

The treatment of symptomatic varicocoeles – or those believed to be the cause of reduced sperm counts – has now become almost exclusively a radiological procedure in which the testicular veins are embolised endoluminally. The surgical treatment consists of ligation and division of the two to four dilated testicular venous channels at the deep inguinal ring. Excessively dilated cremasteric veins, which may be secondarily implicated, can also be ligated. Although it is tempting to undertake scrotal excision of veins, this can result in the loss of a testicle.

PREPUTIAL SURGERY

Except for some minor surgery on the prepuce, surgery of the penis is performed almost exclusively by adult or paediatric urological surgeons or general surgeons who have also undertaken urological training and are offering an additional, relatively comprehensive urological service. However, some descriptions of purely urological operations are included for the benefit of isolated general surgeons who find themselves forced by circumstances to undertake the occasional urological procedure.

Circumcision

Circumcision is performed for congenital and acquired phimosis and for religious and cultural reasons. Circumcision has now been shown to be an effective measure for reducing the incidence of HIV infection.[12] In the infant the foreskin does not retract due to physiological adhesions between foreskin and glans. In the young child, a non-retractile foreskin may be due either to a phimosis or to the persistence of these adhesions. Differentiation is important as congenital adhesions will usually separate spontaneously in the absence of infection, and a circumcision is not required.

Operative procedure

A general anaesthetic is preferable in children, but in adults local infiltrative anaesthesia or regional anaesthesia with a caudal or subpubic block is also satisfactory. The inner and the outer layers of the foreskin are removed. Sufficient skin on the penile shaft must be retained to allow an erection without skin tension, and it is helpful to mark the intended site of the circumferential skin incision before commencing the operation. Excessive suprapubic fat, especially in the young child, may carry abdominal skin onto the shaft of the penis, and before marking, this should be pushed firmly down onto the pubic symphysis so that the shaft is covered only by penile skin (Figure 25.13a). The excision of the inner layer of foreskin should be to within a few millimetres of the coronal sulcus. Too long an inner layer, especially if associated with a long outer layer, can result in a suture line that falls forwards over the glans and may heal with a constrictive circular band, which, again, prevents full retraction.

A variety of circumcision techniques will all achieve good results. The foreskin is first fully retracted, any glandular adhesions separated, the area cleaned with antiseptic and the foreskin replaced. The phimotic band must be stretched or divided to achieve this. Many paediatric surgeons then favour the technique illustrated in Figure 25.13. The tip of the prepuce is grasped with two artery forceps and pulled forwards with light traction. A narrow clamp is placed obliquely across the prepuce distal to the glans and parallel to the corona, after which the prepuce is divided immediately distal to the clamp (Figure 25.13b). The inner layer of the prepuce will still be excessive and so it is trimmed to leave a cuff of about 3 mm (Figure 25.13c). As this technique is inherently dangerous, with great potential for injury to the glans, including even amputation, it cannot be generally recommended.

Most adult circumcisions commence with a dorsal slit between two artery forceps placed close together on the phimotic band in the midline dorsally. Cleaning under the foreskin must usually be postponed until after this incision, as any phimotic band is commonly too dense to stretch. The dorsal incision terminates at the skin mark on the outer layer (Figure 25.14a). The prepuce is then excised circumferentially along the skin mark. This incision, however, always leaves an excessive cuff of the internal layer of the prepuce, which must then be trimmed.

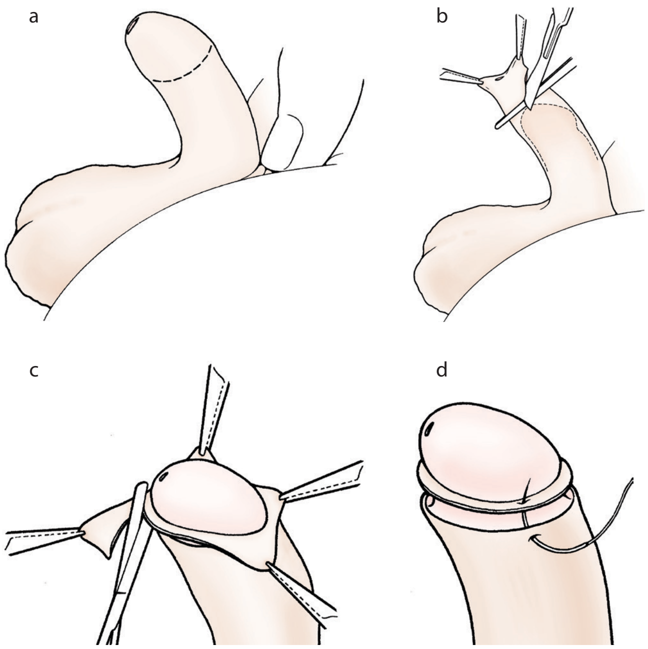

Figure 25.13 *Circumcision. (a) Adequate skin must be left on the penile shaft; it is always safer to mark the intended line of circumferential incision before commencing the operation. (b) A method of amputating the foreskin favoured by many paediatric surgeons. Great care must be taken to avoid injury to the glans. (c) The inner layer of the prepuce is then trimmed. (d) The inner and outer cut layers of prepuce are apposed with fine interrupted sutures.*

The following modification, which avoids the need to trim the inner layer of prepuce, preserves more vessels intact and is suitable for both adults and children, has some advantages. Four artery forceps are applied to the phimotic edge of the foreskin, two dorsally and two ventrally, so that the foreskin can be divided into two lateral flaps. The initial dorsal slit is continued on the inner layer of the prepuce to within a few millimetres of the coronal sulcus. The ventral slit is then made so that the incision in the outer layer reaches the skin mark, but in the inner layer the incision is split into two around the frenular base and then further deviated laterally to continue circumferentially round the inner layer of the foreskin until it meets the dorsal slit incision (Figure 25.14b). As the inner layer of prepuce is divided accurately under direct vision a few millimetres outside the coronal sulcus, no further trimming is necessary. Connective tissue and vessels between the layers of foreskin can often be released and allowed to retract. Finally, the outer layers of the two preputial flaps are divided along the skin mark.

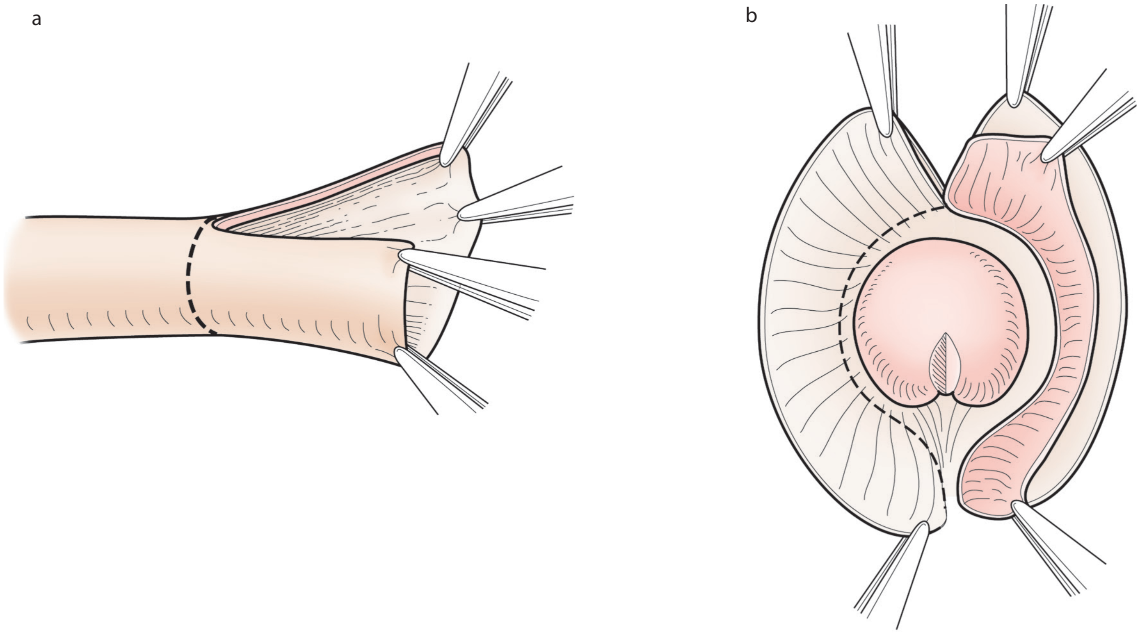

Figure 25.14 *Circumcision. (a) An initial dorsal slit is made between the forceps applied to the free edge of the prepuce. (b) A similar ventral incision has been made but, on the inner layer, it divides to skirt the frenulum. The inner layer of the foreskin has been divided on the right and as it is unfolded, connective tissue and vessels are allowed to retract. On the left the line of the incision is indicated.*

Haemostasis is important, as the most common postoperative complication is haemorrhage. Only *bipolar* diathermy is safe on the penis (see Appendix II) and is satisfactory for most of the bleeding points. A suture may be more effective for frenular bleeding, and in an adult circumcision there may be large veins, which are more secure if ligated. Large divided veins that are in spasm and not actively bleeding are easily overlooked. They are most frequently found beneath the divided outer preputial skin and should be sought as otherwise they will bleed later when venous pressure increases as the patient stands up. Finally, fine interrupted absorbable sutures are used to appose the inner and outer cut edges of the foreskin (Figure 25.13d).

The meatus should be inspected. When the circumcision is performed for balanitis xerotica obliterans, a meatal stenosis may already have developed, necessitating a meatotomy. In children, however, there is often only a plaque adherent to the meatus, which can be lifted off, exposing a raw surface. Application of a steroid cream postoperatively may reduce the incidence of a meatal stenosis developing during healing.

The *hooded foreskin* associated with a minor hypospadias is cosmetically unacceptable, and parents will often request early circumcision. It is important to defer this until it is certain that the skin is not required for reconstruction, remembering that a penis that is bowed when erect has a more major hypospadias than is superficially apparent. The circumcision of a hooded foreskin follows the same general principles, but excision is only required over about five-sixths of the circumference, as the foreskin is absent ventrally.

DORSAL SLIT

This operation is no more than the initial dorsal incision of a circumcision followed by suturing of the wound edges. The phimosis is released and it is a satisfactorily simple solution in the elderly. The cosmetic result is unacceptable to most younger men.

PREPUTIOPLASTY

Preputioplasty is an adaptation of the concept of the dorsal slit, but avoids the cosmetically unacceptable bifid foreskin. Small radial releasing incisions are made in the phimotic band dorsally and at each side. All three incisions are then sutured transversely. Unfortunately, restenosis very often occurs during healing.

FRENOPLASTY

Frenoplasty, a simple transverse release of the frenulum, which is then sutured longitudinally, is indicated for a short frenulum that is tearing on intercourse.

REDUCTION OF A PARAPHIMOSIS

A paraphimosis occurs when a tight prepuce has been retracted beyond the corona and has remained there as a constricting band beyond which the inner layer of prepuce swells rapidly to form an oedematous collar. Manual replacement of the foreskin with one hand, while the other is used to compress the oedematous tissue, is usually successful, but a general anaesthetic may still be required, especially in a child. If reduction fails, the tight band must be surgically incised or a circumcision performed. It is therefore important that the surgical options, including circumcision, have been discussed with the patient and the necessary consent obtained before induction of anaesthesia. A foreskin that has caused a paraphimosis will almost always finally warrant a circumcision but, if reduction can be achieved, this might be better deferred until swelling has settled.

Use of the prepuce in reconstruction

The fine non-hair-bearing skin of the prepuce is an ideal source of full-thickness skin, whether as a local flap or as a free graft. Its mobility and excellent blood supply allow it to be used as a local flap for reconstructive urethral surgery. Preputial skin acquires its blood supply both from the shaft skin and from the coronal sulcus. An incision can therefore be made along the inner layer of prepuce, close to the coronal sulcus, and the whole foreskin unfolded as a long single flap. The mobility of the penile shaft skin makes it possible to rotate this flap to the ventral aspect of the penis, or it can even be brought over the glans, which is buttonholed through the flap.

Alternatively, the foreskin can be mobilised as a separate inner and outer flap with an incision along the free margin of the prepuce (Figures 25.15a, b). The inner flap can be swung round to the ventral aspect for urethral reconstruction, either as an on-lay graft or rolled into a complete tube. It can also be folded down onto the penile shaft to cover a dorsal defect when the ventral skin cover over a urethral reconstruction has been achieved by rotation of the entire shaft skin (Figure 25.15c). Success in all techniques depends on well-vascularised flaps without tension. The foreskin is also a valuable source of skin for free, full-thickness grafts, which can be used not only for skin cover but also as a urothelial substitute in the proximal urethra (see Figure 25.18).

URETHRAL SURGERY

It is important that trauma is minimised during any intubation of the urethra. Whereas the insertion of a flexible catheter through the male urethra can be performed atraumatically with an understanding of the anatomy (Figure 25.16), blind insertion of a rigid instrument is not recommended. Both rigid cystoscopes and flexible fibreoptic cystoscopes should be passed under direct vision, and the urethra is inspected during intubation (cystourethroscopy). Cystoscopy is discussed in Chapter 26. Many urethral procedures can be performed endoscopically. When endoscopic access will be insufficient, an open surgical approach is necessary. The urethra of the penile shaft can be exposed by a subcoronal circumferential incision and proximal retraction of the penile skin. The proximal urethra is approached via a midline incision either anterior or posterior to the scrotum.

Urethral strictures: dilatation and urethrotomy

Strictures in the urethra should be visualised at urethroscopy and they are best treated initially by urethrotomy with an optical urethrotome. A urethrotomy is a clean releasing incision of a stricture after which restenosis on healing is a lesser problem than after dilatation. Subsequently, the stricture can

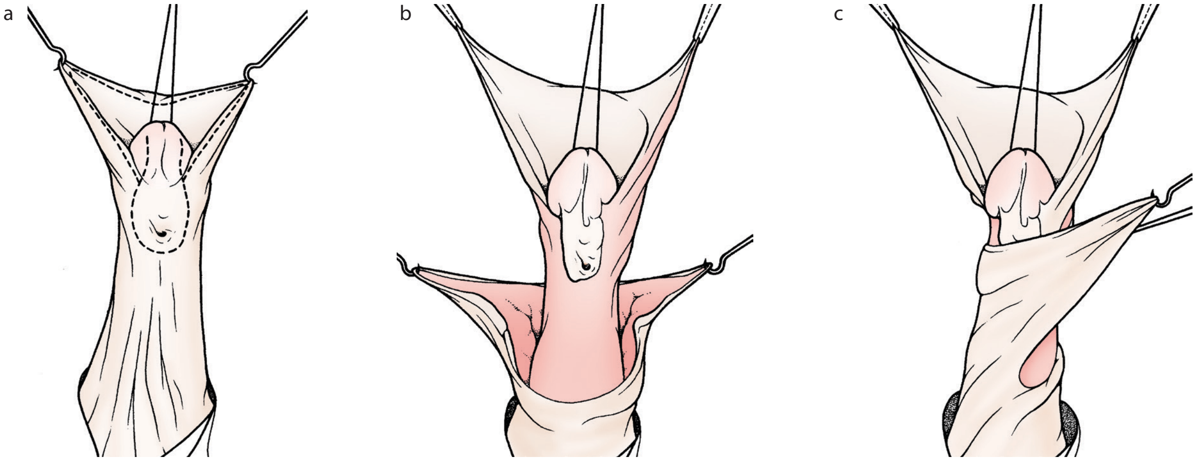

Figure 25.15 *The inner and outer layers of the foreskin can be separated along the free edge. Two flaps, each with a good blood supply, are produced and can be rotated to different areas for reconstruction. In this illustration the hooded foreskin, which is often associated with hypospadias, is shown. (a) The intended incisions have been marked. (b) The outer preputial flap has been mobilised with the penile shaft skin. The inner flap is still attached around five-sixths of the dorsal coronal sulcus. (c) Dorsal penile skin with the outer preputial flap has been rotated to cover a defect on the ventral aspect of the penis. If this leaves a dorsal defect, it can be covered by folding down the flap from the inner layer of the prepuce.*

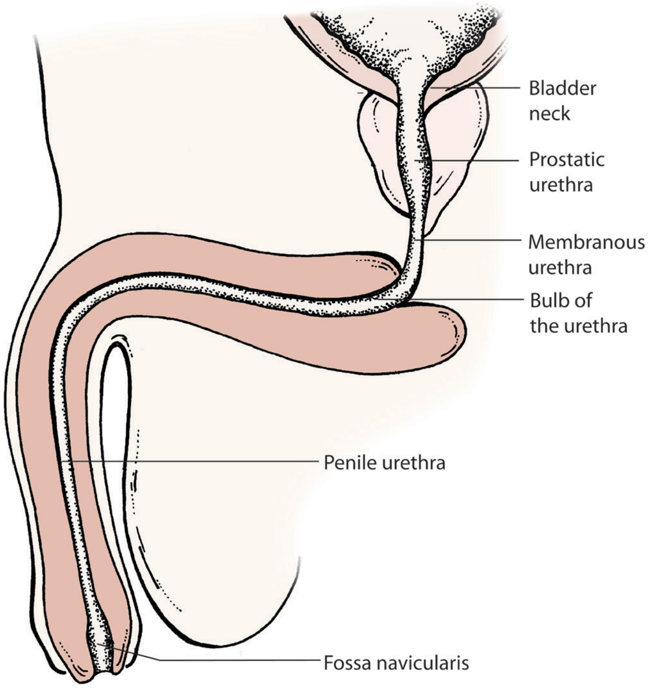

Figure 25.16 *A sagittal section of the male urethra. An appreciation of the change in direction between the bulbar and the membranous urethra is essential for any intubation.*

be managed by repeat urethrotomies or sometimes by passage of a metal sound across the stricture at regular intervals. Alternatively, the patient may be taught to pass a large-bore catheter themself at weekly intervals to prevent restenosis.

Dilatation of a stricture can be accomplished with sequential passage of sounds, but nowadays this should normally only be undertaken where there are no facilities for optical urethrotomy, because blind instrumentation of the urethra risks creation of false passages – a problem that has virtually vanished from centres with optical instruments. The initial sound must be of a diameter that can traverse the stricture *without any force.* It is passed through the stricture and on into the bladder. The sound is tapered and dilates the stricture as it is advanced. Sequentially larger sounds are then passed. For narrow strictures, or strictures that are too long for optical urethrotomy, a guide wire can be threaded through the stricture under direct vision via a cystoscope and further dilators threaded over it. Healing after dilatation is commonly followed by restenosis and dilatation may have to be repeated every few months.

MEATOTOMY

A meatal stricture can be simply dilated, but as restenosis is common and the meatus is easily accessible, a more permanent solution is preferable. A small releasing incision is made and the urethral mucosa sutured to the skin with fine absorbable sutures (Figure 25.17). Following circumcision a meatal stenosis may develop that is in reality only a web partially occluding an otherwise normal meatus. Simple release of this web may be sufficient, followed by self-passage of a dilator to prevent restenosis during healing.

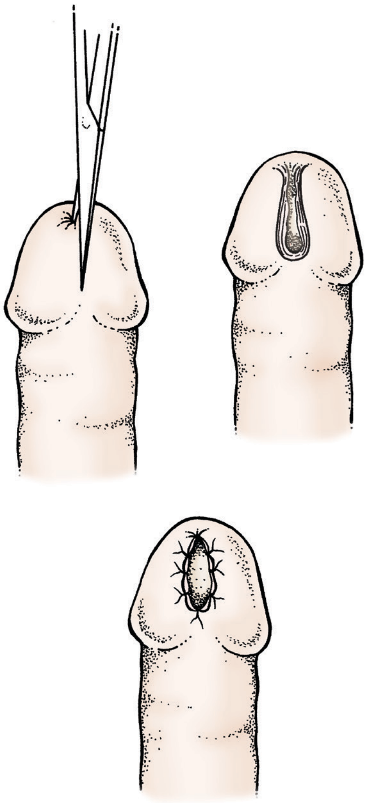

Figure 25.17 *A meatotomy. Restenosis is prevented by the sutured mucosal–skin apposition.*

Urethroplasty

Urethral strictures that are long, dense or recurrent may be better treated by reconstruction than by repeated dilatations or urethrotomies. Access to the more posterior strictures is through the perineum posterior to the scrotum. It is sometimes practical to excise a short stricture and anastomose the urethral ends, but a patch urethroplasty is usually a better solution. The buccal mucosal graft gives very good results, and is technically easy to learn. The urethra is exposed and opened along the length of the stricture (Figure 25.18a). A full-thickness patch graft (the mucosal layer on the inside forming the urethral lumen) is then sutured to the edges of the opened urethra with fine absorbable sutures (Figure 25.18b). Alternatively, the free graft can be taken from the inner layer of the prepuce. Pedicled skin grafts from the adjoining scrotal or penile skin have, in general, been superseded, as hair formation in the neourethra can be troublesome. The skin is then closed over the reconstructed urethra and a fine silastic urethral catheter is left *in situ* during healing.

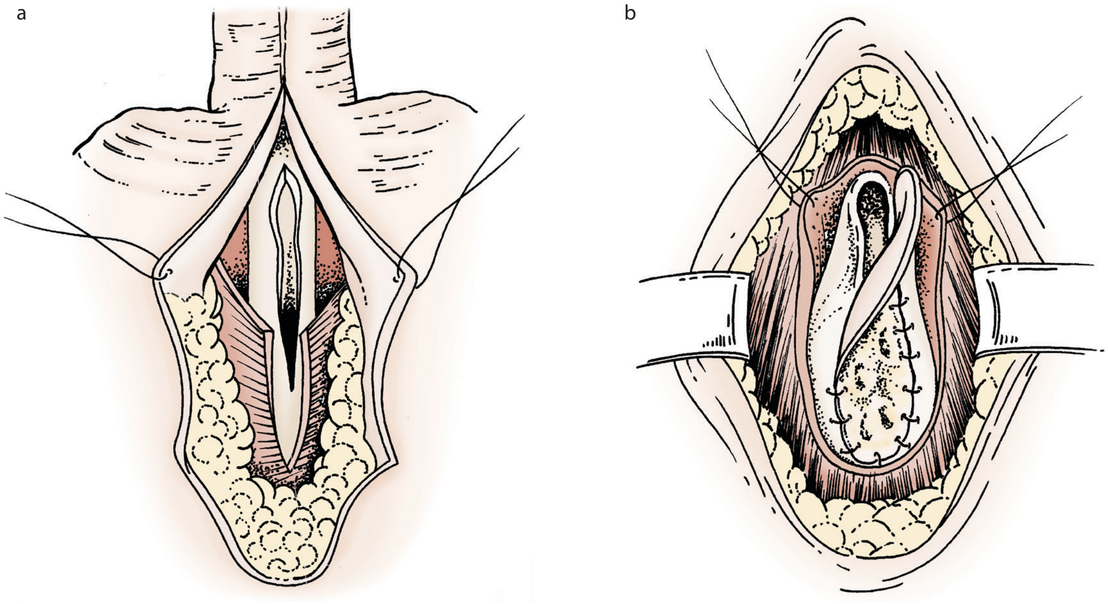

Figure 25.18 *A patch urethroplasty. (a) The whole length of the stricture and a short segment of healthy urethra proximal and distal are laid open. (b) A buccal mucosal graft is sewn to the cut edges of the urethra. The mucosal surface must face into the urethral lumen. The skin edges are closed over the mucosal patch.*

Two-stage urethroplasty

A two-stage urethroplasty may still have a place when there are fistulae and sinuses or excessive scar tissue from previous infection or surgery. This may well be the situation with which a general surgeon, working in an area with limited healthcare facilities, is faced. A temporary suprapubic catheter should be considered. An alternative is the creation of a perineal urethrostomy, as described below, to allow time for sepsis to settle, because once it has done so, a long buccal mucosal patch urethroplasty may be feasible.

An inverted **U**-shaped incision is made behind the scrotum (Figure 25.19a). A longitudinal extension of the skin incision is then made forwards between the two halves of the scrotum and the flaps of skin and fat elevated. The urethra is incised over the whole length of the stricture, and this incision must extend into healthy urethra both proximally and distally (Figure 25.19b). The cut edges of the urethra are then sutured to the edges of the longitudinal skin incision, except proximally where instead the apex of the **U**-shaped flap is sewn to the proximal end of the laid-open urethra to form a

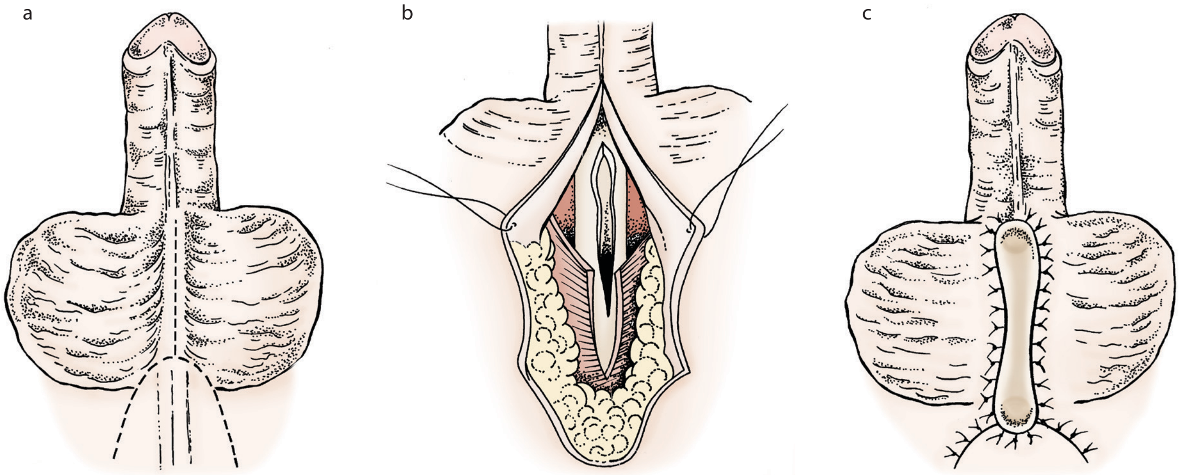

Figure 25.19 *A two-stage urethroplasty. (a) The initial inverted* **U**-*shaped incision. (b) The whole length of the stricture is laid open, including a short segment of healthy urethra both proximal and distal to the stricture. (c) The cut edges of urethra are sewn to the skin so that the segment of stenosed urethra is exteriorised as a groove in the perineal skin. The proximal opened urethra is sewn to the skin of the apex of the flap.*

temporary perineal urethrostomy (Figure 25.19c). The remainder of the flap is replaced. This first stage has on occasion been performed as an emergency when a patient presents with a para-urethral abscess associated with an impassable stricture. The external drainage of the abscess is then combined with release of the stricture and the formation of a temporary perineal urethrostomy.

The traditional second stage of this operation was to use the scrotal skin to complete the urethral tube, but a long buccal patch, as shown in Figure 25.18b, provides a much more satisfactory result.

Urethral injury

Urethral injury is very rare in women except as a consequence of prolonged untreated obstructed labour. Urethral injury must always be considered in male patients with a penile or perineal injury. Urethral injuries are also associated, particularly in the male, with displaced anterior pelvic fractures, and these patients frequently have multiple other injuries.

Early bladder catheterisation may be indicated for the monitoring of a severely injured patient. Alternatively, a patient with an isolated penile or perineal injury may have developed urinary retention, and it should be remembered that this is the most frequent clinical course in a man with urethral disruption. When a urethral injury is suspected, the safe initial management is suprapubic catheterisation followed by specialist urological assessment. However, when it is thought that injury is relatively unlikely, it is reasonable to attempt urethral catheterisation. A large soft catheter, when passed through a urethra distended with lubricating jelly, is least likely to compound any damage. Adequate analgesia is essential. One-and-a-half tubes of anaesthetic lubricating jelly is inserted into the urethra, but is not massaged up. The urethra is held closed to prevent the jelly escaping, and the remaining jelly used to lubricate a size 16 or 18 soft (preferably silicone) urethral catheter. If the catheter passes easily into the bladder, with drainage of urine, significant urethral injury is unlikely. If passage becomes difficult, the procedure is stopped and a suprapubic catheter is placed, ideally under ultrasound control.

Penile urethral injuries may be associated with lacerations into the erectile tissue and large haematomas. Early exploration with evacuation of the haematoma and direct repair of both the urethra and the erectile tissue will give the best results.

Membranous and supramembranous urethral injuries are often circumferential, and the continuity of the urethra is completely lost as the prostate and bladder neck dislocate upwards and backwards (Figure 25.20a). Rectal examination may demonstrate the displaced prostate. Suprapubic catheter drainage should be established, and arrangements made for the patient to be managed by a surgeon with experience of these injuries. Direct surgical repair of the injury is difficult but, in skilled hands, is now believed to provide the best results. It must, however, be delayed for several days while bruising and oedema settle. The traditional manoeuvre of re-establishing urethral continuity, without formal repair, was by passing one metal bougie up the urethra and a second one down through the bladder neck from an open cystostomy. It was then possible to manipulate the displaced tissues into position so that the two bougies touched (Figure 25.20b). The distal bougie could then be guided up into the bladder in contact with the upper one as it was withdrawn. The external end of a catheter was fitted over the end of the bougie and drawn retrogradely through the urethra. It was then attached to a balloon catheter, which was drawn up into the bladder. After inflation of the balloon, gentle retraction held the reduction and urethral apposition. Healing with stricture formation was common and final continence

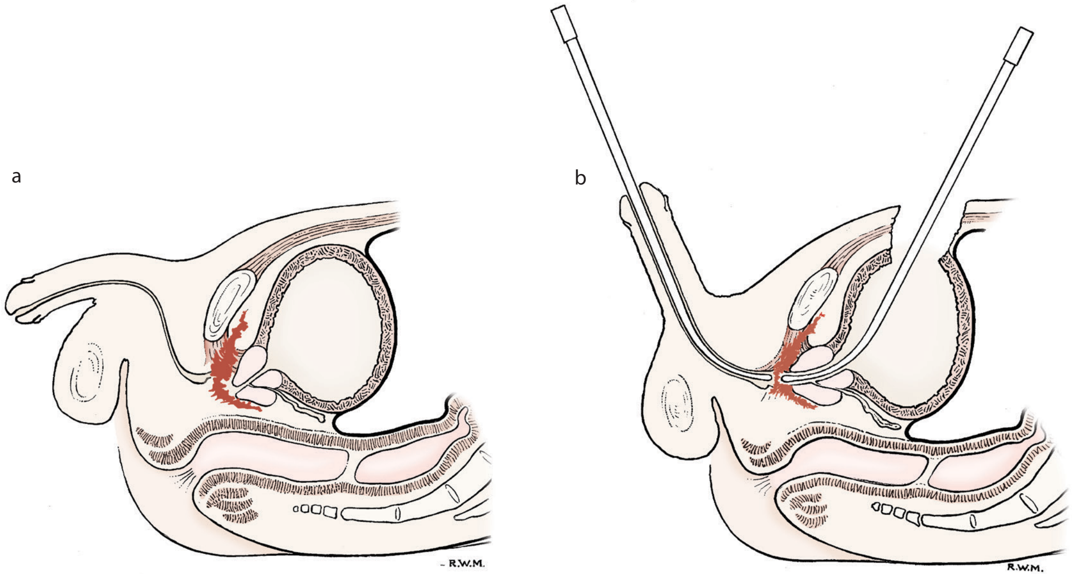

Figure 25.20 *This simple method of alignment of a disrupted membranous urethra is no longer recommended, as the long-term results are poor.*

was often poor. This, now historic, technique is described only as it may be the sole practical option for a general surgeon with no access to urological expertise.

Hypospadias

A hypospadiac urethra may open on the ventral aspect of the glans, the coronal sulcus or the penile shaft, or even onto the perineum. Many different reconstruction techniques have been developed.[13] The surgery of hypospadias is specialised and is carried out almost exclusively by paediatric urologists or plastic surgeons, although it is important that any surgeon undertaking circumcisions in childhood is aware of the potential value of the associated hooded foreskin for reconstruction.

The hypospadiac meatal opening may be stenosed and a meatotomy may be required prior to the full reconstructive operation, which is ideally performed between 6 and 12 months of age. In some cases the hypospadias is associated with *chordee*, in which the infant's erect penis is ventrally bowed by abnormal fibrous tethering of tissue on the ventral aspect of the penile shaft. The diagnosis of chordee can be confirmed by creating an artificial erection under anaesthesia. A constricting band is placed around the base of the penis and normal saline is injected into the erectile tissue. It is a useful test at the start of surgery, and also to check during the operation whether surgical release has been sufficient.

The significance of the *urethral plate* is now fully appreciated. This is the strip of urethral mucosa extending from the hypospadiac meatus onto the glans and is thus ideal tissue with which to fashion the neourethra. However, this strip was initially thought to be the main factor tethering the short urethra to a more distal position on the penis than it could reach, and thus the cause of any chordee. It was therefore often sacrificed in the initial dissection. It is now known that the problem is mainly that of abnormal fibrous attachments of often deficient proximal shaft skin to the underlying erectile tissue and not to the urethral plate itself.

The first step in the repair of a hypospadias is the release of chordee, if present, by degloving the penile shaft. Any fibrous tissue representing atretic corpus spongiosum is excised and the urethral plate is seen to lengthen and narrow as the chordee corrects; the meatus may then lie more proximally on the penile shaft than previously.

When the urethral plate is of inadequate length after release of the underlying adhesions, grafts or flaps are required to construct the neourethra and full reconstruction may have to be a staged procedure. A free graft of inner preputial skin or buccal mucosa is suitable for this first stage. However, if the urethral plate is of sufficient length, it can now be rolled over to form a complete neourethra if it is sufficiently wide (Figure 25.21). Often, it is too narrow but can still be used to form half of the circumference. In the widely performed tubularised incised plate urethroplasty (Snodgrass technique), reliance is placed on the concept that a buried skin strip forms an epithelial tube by proliferation from the edges. This procedure was initially described for distal hypospadias,[14] but has proved applicable in most situations. The urethral plate is incised longitudinally in the midline throughout its length so that the two halves of the plate can separate as the lateral edges are drawn over and sutured to form a tubular extension to the hypospadiac urethra (Figure 24.22). Skin cover is then required for this neourethra. Penile skin is mobile and elastic, and the skin from the outer layer of the hooded foreskin can be brought to the ventral aspect of the penis by a number of manoeuvres.

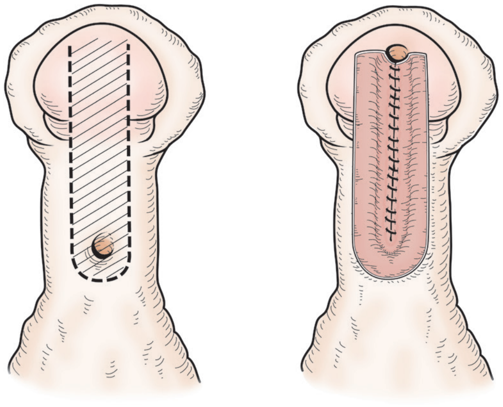

Figure 25.21 *The wide urethral plate, shown as the hatched area, has been released, rolled and sutured to form a neourethra. Skin cover is now required for the shaded area.*

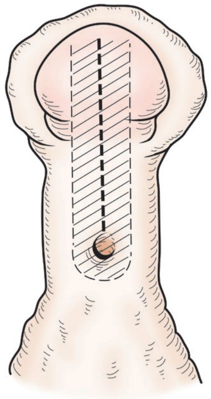

Figure 25.22 *The midline incision allows a tension-free tubularisation of a narrow urethral plate. Epithelium grows in to cover the deficient dorsal strip of the neourethra.*

The surgery is very delicate. Fine absorbable sutures are used (6/0 or 7/0) and magnification devices may be helpful. A tourniquet will provide control of bleeding during surgery. Broad-spectrum antibiotic cover should be used and urethral or suprapubic catheter drainage instigated for around 7 to 10 days.

SURGERY OF ERECTILE TISSUE

Trauma

A tear of the tunica albuginea may occur from a penile laceration or fracture of an erect penis. A circumferential subcoronal incision allows the loose penile skin to be retracted proximally, thus exposing the entire penile shaft. Haematoma is evacuated and the tunica repaired with strong, long-acting absorbable sutures. An associated injury to the penile urethra should be sought and repaired if present. Catheter drainage should be instituted.

Priapism

Detumescence can usually be achieved by insertion of a 16-gauge cannula into the corpora and aspiration of blood, followed by injection with normal saline. If unsuccessful, treatment is then pharmacological, with local injection of phenylephrine. As a last resort, shunts can be created by taking a Tru-Cut® biopsy of the fascia separating the corpora spongiosum and cavernosum. The Tru-Cut® needle is introduced bilaterally through the glans and advanced in line with the penile shaft into each corpus cavernosum.

Penile amputation

Squamous cell carcinoma of the penis usually arises beneath the prepuce. Although it is perceived as an old man's cancer, UK statistics show this cancer to be occurring in men from age 40 years onwards, and survival is poor. Whenever possible, treatment should be undertaken in the context of a multidisciplinary cancer team, as the surgical and non-surgical options depend on the stage of the cancer. Surgical options include local removal and skin grafting of the glans, various levels of amputation and complete penile removal with a perineal urethrostomy. If there is invasion of more than 2 mm in depth, bilateral or unilateral lymph node dissection is usually indicated. In the absence of such an approach, penile amputation is often undertaken, although this will be undermanagement in some cases and overmanagement in others.

In a penile amputation the amputated corpora are oversewn and skin flaps brought over the end. It is essential to form a mucosal–skin anastomosis of the urethra to prevent stenosis. The urethra can be brought out either through the suture line or through the longer flap (Figure 25.23). Very late presentation is common in remote hospitals, and the surgeon is faced with a fungating growth that has destroyed the penis and is invading the scrotum. A total excision of penis and scrotum with the urethral stump anastomosed to the perineal skin as a perineal urethrostomy may be the only surgical solution that will give local control. This may have to be followed by an inguinal node dissection for control of nodal metastases.

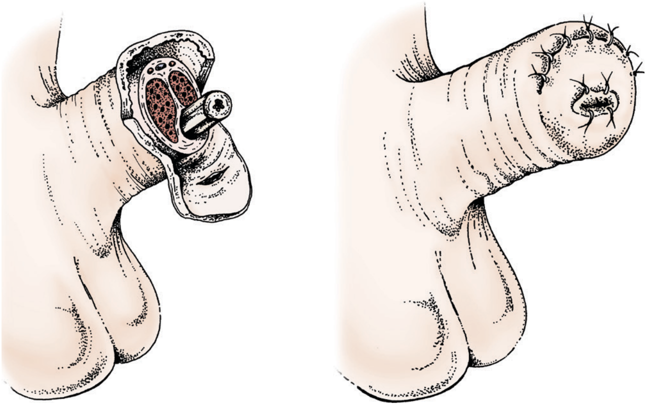

Figure 25.23 *An accurate mucosa–skin apposition is essential to prevent stenosis of the new meatus after penile amputation.*

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There is increasing specialisation within all branches of surgery, and urology is now considered in most countries to be a separate surgical speciality from general surgery. In some parts of the world, either because of low population density or poor healthcare resources, there is a need for surgeons with a very wide remit. As the practice of these surgeons often includes both general surgery and urology, it is important that they have also received specialist training in urology. Some basic urology has been included in this chapter both for the benefit of the general surgical trainee who is working in a remote unit where urology still forms part of general surgical practice, and also for the isolated general surgeon whose practice must occasionally encompass urological problems. The coverage is, of necessity, limited and more comprehensive urological texts should be consulted.[1,2]

However, even the general surgeon whose practice does not include urology must still understand the principles underlying this branch of surgery – just as the urologist should understand general surgery. Cooperation between the specialities is often required, both for reconstructive procedures and for advanced pathology involving adjacent organs. Damage to a ureter or to the bladder may occur during a general surgical or gynaecological operation. In most situations, a general surgeon who unexpectedly encounters, or causes, urological trauma, or who encounters pathology that extends into urological organs, can obtain the assistance (or at least the advice) of a urological colleague. Occasionally, however, a general surgeon may be forced by circumstances to operate in ‘urological territory’, often in the absence of any specialist expertise or equipment.

GENERAL PRINCIPLES

Renal function

No surgery should be undertaken on a kidney or ureter without knowledge of the function of both that kidney and the other kidney. In elective urological surgery, preoperative imaging and more sophisticated tests of differential function, if indicated, will have been carried out. In the situations in which a general surgeon may be involved, this information is often scant or absent. Palpation at operation can identify the anatomical presence of a second kidney, but provides no information on function. In cases of unexpected retroperitoneal or pelvic masses, beware the ectopic kidney! A preoperative intravenous urogram (IVU) or a CT scan with contrast will demonstrate where the kidneys are and whether they are functioning. If neither investigation has been performed, an on-table IVU is recommended. A single, high-dose late film, taken at 20 minutes, should provide the maximum information.

Renal vascularity

The kidneys receive one-fifth of the total cardiac output, and haemorrhage from the kidneys can be profuse. This may render any surgery *through* the renal parenchyma and any surgery to repair renal trauma extremely difficult (see Chapter 15). Temporary vascular control of the renal vessels may be essential, and the anterior approach, in which access to the renal pedicle is superior, is recommended in these circumstances. During vascular occlusion it must be remembered that renal tissue is damaged by ischaemia faster than any other tissue, except brain.

Urinary drainage

In any functioning kidney, urine will continue to collect in the renal pelvis and adequate drainage to the bladder or to the exterior is essential. An obstructed kidney eventually ceases to function, and over time this functional loss becomes irreversible. Bilateral obstruction can thus cause acute kidney injury or chronic renal impairment. It should also be remembered that severe bladder outlet obstruction can eventually cause bilateral upper urinary tract obstruction. Stagnant urine is also prone to infection.

- A *nephrostomy* drains the urine directly to the exterior.
- A *ureteric stent,* placed between the renal pelvis and bladder, improves drainage of urine to the bladder.
- A *urethral* or *suprapubic catheter* is employed to drain an obstructed bladder. Free catheter drainage of the bladder is also recommended for 10–14 days after closure of a surgical or traumatic bladder incision, as normal micturition pressure can cause disruption.

Malignant ureteric obstruction. Advanced pelvic malignancies may cause unilateral, or bilateral, ureteric obstruction. Often, the diagnosis of inoperable, or recurrent, cervical, prostatic, bladder or rectal cancer is already established but the patient presents with anuria. Nephrostomy drainage or the placement of ureteric stents (from either above or below) across the malignant stricture will prolong life. It may, however, deny the patient a relatively pain-free ureamic death and prolong the suffering from advanced pelvic malignancy.

Patients who present with ureteric obstruction before a definitive diagnosis has been reached pose combined challenges of diagnosis and initial management. Malignancy should be confirmed histologically, and benign retroperitoneal fibrosis excluded. The occasional malignancy is still amenable to curative surgery at this stage, but this is uncommon. Other malignancies may respond to radiotherapy, chemotherapy or hormone manipulation, with the potential for regression and long-term palliation. Initial nephrostomy or ureteric stents will therefore be required at least until tissue diagnosis is obtained and decisions reached on appropriate management.

Stone formation

Any foreign body in contact with urine can stimulate stone formation; consequently, all sutures must be absorbable. Stents and catheters will eventually encrust, although the materials from which long-term catheters are fashioned are designed to reduce this. A high fluid intake, with resultant dilute urine, also reduces encrustation, although stents and catheters should still be changed approximately every 3 months.

SURGICAL ANATOMY

The kidneys

The kidney is enveloped in a *fibrous capsule* and consists of the parenchyma and the collecting system. The glomeruli are within the outer parenchyma or *cortex.* The collecting tubules in the inner parenchyma, or *medulla,* open on the papillae into the *calyces* of the collecting system. The calyces unite to form the *renal pelvis.* The collecting system lies partially enclosed within the renal parenchyma, but usually some portion of the renal pelvis lies extrarenal before it tapers to the *pelviureteric junction.* The *renal fascia* encloses the kidney, the adrenal gland and the perinephric fat (Figure 26.1).

The *renal pedicle* consists of the renal vein, which lies anterior, the ureter, which is posterior, and the renal artery, which lies between the two. The right renal vein is short as the right kidney lies very close to the inferior vena cava (IVC) (Figure 26.2). Anatomical variants are common and include

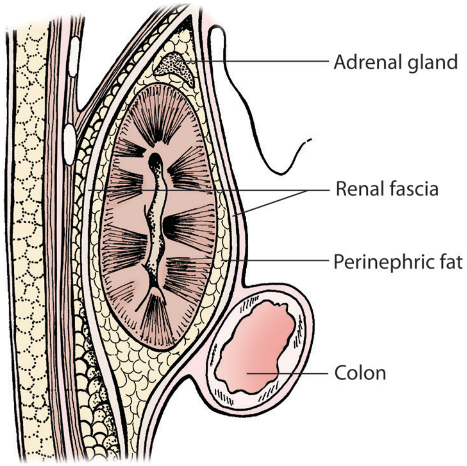

Figure 26.1 *A sagittal section of a kidney showing its relationships to perinephric fat, adrenal, renal fascia, pleura and colon.*

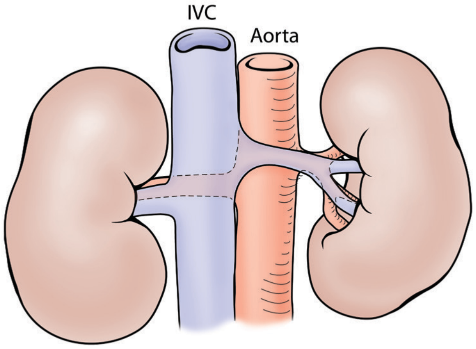

Figure 26.2 *The standard vascular anatomy of the renal pedicle. The right renal vein is short. The longer left renal vein crosses anterior to the aorta. The renal arteries, which may be multiple, are behind the veins. Nephrectomy is, in essence, an operation on the great vessels.*

variable hilar vascular anatomy, complete or partial duplex systems, horse-shoe kidneys and crossed ectopia, in which a kidney lies on the opposite side from the insertion of its ureter. All may confuse the unwary.

The duodenum and hepatic flexure lie anterior to the right kidney: the splenic flexure, pancreatic tail and spleen are closely applied to the left (see Figure 14.2, p. 229). The kidneys lie retroperitoneally and may be approached, at open or laparoscopic surgery, from the abdomen or from the loin. An open abdominal approach may be retroperitoneal, but is more commonly transperitoneal; the loin approach is retroperitoneal. The abdominal and loin incisions for open surgery are described in Chapter 13. Laparoscopic renal surgery can also be performed using either approach, but is most commonly performed transperitoneally.

The ureters

The ureters commence at the pelviureteric junctions and run distally in the retroperitoneum to end at the ureteric orifices in the bladder. Their final intravesical segment runs an oblique course through the bladder wall musculature, which acts as a valve during bladder filling and micturition, preventing ureteric reflux. The ureteric wall is muscular and visible contractions, or *vermiculation*, enable the surgeon to identify the ureters at laparotomy.

X-ray position. On an IVU, classically the course of the ureters lies from the renal pelvis down the tips of the transverse processes of the lumbar vertebrae, over the sacroiliac joints, laterally towards the ischial spines and then medially to the bladder.

During intra-abdominal surgery the ureter must be identified early in any operation that might place it at risk of injury. Mobilisation of the caecum or pelvic colon commences with incision of the peritoneum lateral to the bowel, which is then swung medially. Dissection proceeds with great care and the ureter is identified. It lies behind the gonadal vessels on the psoas muscle and crosses the pelvic brim approximately at the bifurcation of the common iliac vessels. It is therefore also at risk in aortoiliac vascular surgery. In the pelvis the ureter is at greatest risk as it turns medially towards the trigone of the bladder. It crosses underneath the uterine arteries in the base of the broad ligament (hence the saying ‘water under the bridge’) and may be inadvertently included in the ligation of the uterine arteries during hysterectomy.

In any difficult pelvic dissection, the ureters should be identified above the pelvic brim and followed on their anterior surface into the pelvis and towards the bladder. A tunnel is created by gently inserting an artery forceps distally along the anterior surface of the ureter from the portion that is already displayed. Tissue lying anterior to the ureters can be safely divided. This plane can be followed until the ureter enters the bladder wall. Ureteric catheters or stents make ureteric identification easier, and the general surgeon, when embarking on a pelvic dissection where difficulty is anticipated, will find the short delay while a urological colleague places the stents amply rewarded. In patients in whom it will be most helpful, the placement of ureteric catheters may also be difficult due to distortion of the anatomy.

The bladder and prostate

The bladder lies behind the pubis and is mainly extraperitoneal, lying below the peritoneal reflexion. In the male it is separated inferiorly from the pelvic floor musculature by the prostate gland and posteriorly it is separated from the rectum by the seminal vesicles and Denonvillier’s fascia (Figure 26.3). In the female, the bladder lies directly on the pelvic floor and is separated posteriorly from the rectum by the vagina. The ureters enter the bladder posterolaterally within a centimetre or two of the internal urethral opening.

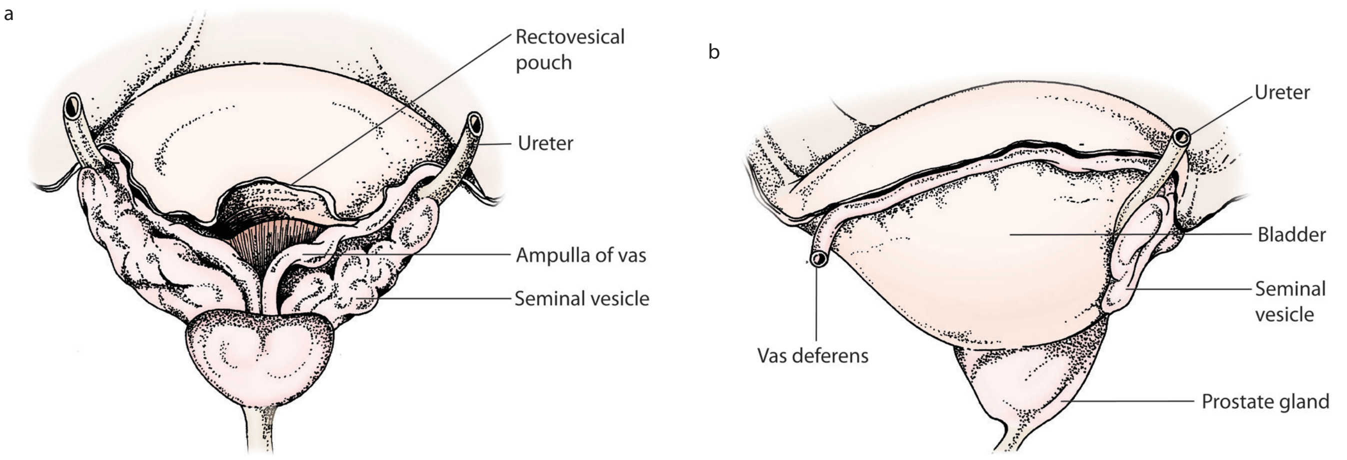

Figure 26.3 *(a) The posterior view of the bladder. (b) A lateral view of the bladder.*

RENAL TRAUMA

Renal trauma is discussed in Chapter 15.

NEPHRECTOMY

The most common operation that a general surgeon will perform on the kidney will be a nephrectomy, either as an emergency for trauma, in which case the abdomen is often already open, or, more rarely, for resection of a malignant mass that is found to involve a kidney. When a nephrectomy is undertaken as a planned procedure, following preoperative investigations that indicate pathology confined to the kidney, there is a choice of the abdominal or the loin approach. The transperitoneal *abdominal approach* is usually considered superior in renal malignancy for the better access it gives to the great vessels, and a subcostal incision affords excellent access for almost all renal surgery. However, for very large upper renal tumours a thoracoabdominal approach, with or without liver mobilisation, provides very extensive access. The alternative retroperitoneal *loin approach* for nephrectomy may be preferable in elective surgery for infective and other benign conditions. *Laparoscopic nephrectomy* is now the method of choice when nephrectomy is required for benign disease or for T1-T2 renal cancers. Smaller renal cancers are increasingly managed by partial nephrectomy, which may be performed laparoscopically in specialised centres.

Anterior approach

The abdomen may already have been opened through a midline incision for an emergency laparotomy or for a large bowel resection. When access is required only for a nephrectomy, a transverse-orientated incision or subcostal chevron incision may be preferred. The peritoneum is opened and the small bowel packed into the opposite side of the abdomen. On the right side, the peritoneum of the posterior wall is incised along the lateral aspect of the ascending colon, hepatic flexure and second part of the duodenum. The colon, duodenum and head of the pancreas are swung medially to expose the anterior surface of the kidney and its pedicle. On the left the peritoneal incision is along the lateral aspect of the descending colon and spleen, which are then swung medially with the pancreatic tail.

Mobilisation and vascular control

Dissection around the kidney allows full mobilisation of the organ. In benign pathology, the plane immediately outside the fibrous capsule of the kidney may be followed, although in cases where there is severe fibrosis secondary to infection it may be easier to remain outside the perinephric fat. In renal tumours a plane should be followed *outside* the perinephric fat, which is resected with the kidney (see Figure 26.1). If there is good preoperative imaging and there is no evidence of tumour in the adrenal, it is no longer considered necessary to remove the ipsilateral adrenal gland, whereas it used to be routine to do so, especially for upper pole tumours. Adrenal vessels can be difficult to secure, particularly the right adrenal veins, which may lie high in the triangle between the liver and the IVC and open directly into the IVC.

A large renal tumour may have acquired additional vascular supply and drainage from surrounding tissues, and additional vessels will have to be secured. Many accessory peripheral dilated veins should warn the surgeon that the main venous drainage may be obstructed by tumour, if not already shown on preoperative imaging. A renal cell carcinoma (hypernephroma) may also invade the renal vein and grow within its lumen. It may, therefore, be necessary to open the IVC to remove intravascular tumour. In advanced cases this is often only possible to accomplish with the aid of circulatory arrest and/or cardiopulmonary bypass.

During mobilisation, excessive traction on the renal pedicle must be avoided or tears of major veins can occur. Early ligation of the renal vessels, prior to full mobilisation, reduces vascularity and is one advantage of the abdominal over the loin approach. In the pedicle, the renal vein lies anteriorly and the surgeon approaching from the front may be tempted to ligate this first to improve access. A kidney with the venous return ligated, but the arterial inflow intact, will enlarge and any haemorrhage from it will dramatically increase. It is nearly always possible to ligate the artery as the initial vascular procedure (Figure 26.4). In situations where there is a large right renal tumour closely applied to the IVC, it can help to ligate the right renal artery by approaching it between the aorta and the IVC. Change in colour of only a portion of the kidney should raise the suspicion that there is more than one renal artery. Artery, vein and ureter should be ligated separately.

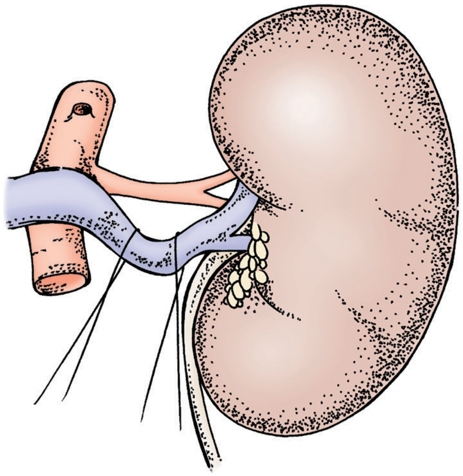

Figure 26.4 *The left renal vein has been retracted to expose the renal artery. It can be retracted cranially or caudally. Ligation of the artery before the vein prevents renal engorgement.*

The vessels should be ligated in continuity prior to division; double ligation or transfixion ligation for additional security is recommended. The ligation should be undertaken with a thick-gauge absorbable ligature, such as No. 1 Vicryl®. Silk sutures should no longer be used as they are associated with an appreciable incidence of postoperative sinus formation, with discharge of suture material over many years. The practice of clamping, dividing and only then ligating the vessels is not recommended as haemorrhage can be torrential if a clamp slips. Linear stapling devices are an excellent alternative, particularly at laparoscopy, but may not be available and are associated with a significant increase in cost. The right renal vein is short and may be difficult to ligate in the way described, especially if there is tumour in its lumen. If this is so, a Satinsky clamp can be applied laterally on the IVC where the vein enters (see Figure 6.2, p. 86). The vein is then divided distal to the clamp and the IVC sutured with a continuous 5/0 vascular suture before the clamp is removed. When undertaking renal surgery it is always wise to have a Satinsky clamp immediately available.

If the kidney has been operated on before or is infected, and there are dense adhesions, it may be impossible to identify, isolate and ligate the vessels in the way described. In such cases the pedicle can be clamped *en masse* and the kidney removed, leaving, beyond the clamp, sufficient tissue to allow the stumps of the main vessels to be picked up with forceps and ligated separately before removing the clamp. If even this manoeuvre is impossible, the pedicle may be ligated *en masse*, using a heavy absorbable transfixion suture. Where there has been prolonged severe infection, the plane between the capsule and the surrounding fat may have been obliterated. A more radical approach, similar to that employed for malignancy, may be preferable, as this will give good exposure of the vessels. However, very occasionally the inflammation is such that all planes appear obliterated, and it may be necessary to perform a subcapsular nephrectomy. Even when there is the most marked inflammatory change, the subcapsular plane remains intact. An incision is made through the renal capsule on the lateral aspect of the kidney and, by finger and gauze dissection, the plane of cleavage between it and the kidney is opened up. The separation is continued on all surfaces as far as the pedicle, where the everted capsule must be incised so that the vessels of the pedicle can be dissected out.

Finally, the ureter is ligated and divided and the kidney is lifted free from its bed.

Haemorrhage from the renal pedicle

Haemorrhage from the renal pedicle can occur because a clamp or ligature may have slipped or a vessel may have been injured during dissection. Profuse bleeding obscures all structures. In this situation the first rule is not to panic. No attempt should be made to secure the bleeding vessel by plunging artery forceps into a pool of blood in the hope that the vessel and nothing else will be picked up. Instead, gauze packs are pressed into the wound and the haemorrhage controlled by digital pressure. The anaesthetis should be advised of the situation so that adequate venous access can be assured and blood obtained from the transfusion service. If possible, call for extra assistance. If the haemorrhage is from a divided vessel, it should be possible to remove the packs after a delay of at least 10 minutes and find that the bleeding has slowed enough for the severed vessel to be seen and secured. More frequently, especially on the right, the bleeding is from a side tear in the IVC. This bleeding will not reduce spontaneously, as a partially divided vessel cannot close with spasm. Digital pressure through swabs can temporarily control the situation. The pressure is then withdrawn sequentially from above until recommencement of bleeding indicates the proximal extent of the caval tear. A continuous vascular suture, such as 4/0 Prolene™, is started at this point, and continued distally as the digital control is sequentially withdrawn down the IVC. It is sometimes possible to apply a large Satinsky clamp to isolate the tear while it is sutured.

Open loin approach

This is an approach favoured for an elective nephrectomy for benign conditions or for open partial nephrectomy for small renal tumours, and it is also suitable for nephrectomy for early malignant tumours of the kidney that have not breached the renal capsule. It is, therefore, an approach of more limited value to the general surgeon. The loin incisions for this operation are described briefly in Chapter 13. Care is taken to sweep the peritoneum anteriorly, and the perinephric fat is opened to expose the lateral border of the kidney. The renal capsule is freed from the perinephric fat and once the upper pole has been freed, the kidney becomes much more mobile. Dissection of the pedicle and division of the artery, vein and ureter will then allow the kidney to be removed. The modifications that may be necessary when there are dense adhesions from chronic infection are described above.

Laparoscopic extraperitoneal approach

Urologists who have developed laparoscopic skills are prepared to undertake an increasing range of operations on the kidney, including partial nephrectomy. The recovery time is greatly reduced, as both the anterior and the loin wounds required for open surgery may be a significant source of early postoperative pain and morbidity. However, if bleeding occurs during a laparoscopic nephrectomy it can be very difficult to control, and consequently patients must always be warned that there is a risk of conversion to open surgery.

It must be remembered that the duodenum and colonic flexures are in close association with the anterior surface of the kidneys and are vulnerable to injury even when a retroperitoneal approach has been used, whether open or laparoscopic. A general surgeon must bear this in mind when asked by a colleague to see a postoperative urological patient who has any abdominal signs suspicious of peritonitis.

Nephroureterectomy

In this operation the whole length of the ureter is excised in continuity with the kidney. It is the standard treatment for *transitional cell carcinoma* in the renal pelvis, calyces or ureter. After completion of the nephrectomy at open surgery, the kidney is left in the wound attached to the ureter, but nothing else. If a laparoscopic approach has been used for the nephrectomy part of the procedure, then the kidney is usually placed in a retrieval bag and left in the abdomen. The nephrectomy wounds are closed and the lower part of the ureter is approached through a separate incision in the lower abdomen. The ureterovesical junction is exposed by dividing the superior vesical vascular pedicle. Careful blunt dissection through the muscle of the bladder will liberate a delta-shaped protrusion of mucosa, which will include the ureteric orifice. This is circumcised and the bladder is closed with absorbable sutures. The suture line is protected by an indwelling urethral catheter left on free drainage for 10 days. The kidney and attached ureter are removed through the lower abdominal incision.

Heminephrectomy

This operation, which can be performed by an open or a laparoscopic approach, is indicated when one moiety alone of a *duplex kidney* is severely damaged by infection or trauma. There may be obstruction or reflux in one of the duplex ureters, with subsequent stone formation, infection, renal scarring and loss of function only in the part drained by that ureter. The associated vascular separation of the two halves makes a heminephrectomy an attractive option. The hilum is dissected to identify vessels and ureters to the moiety to be removed. After ligation of these vessels, the two moieties can be separated with minimal blood loss.

Partial nephrectomy

Partial nephrectomy is a more difficult procedure than a total nephrectomy due to renal parenchymal vascularity and, in contrast to a heminephrectomy in a duplex kidney, there is no natural anatomical separation to aid the surgeon. The operation should, however, be considered when only one part of the kidney is involved in pathology but the remainder of the kidney is healthy. Stone formation in a non-duplex kidney is an occasional indication for a partial nephrectomy. Although *renal tuberculosis* can be eradicated with anti-tuberculous drug therapy, a solitary calyceal ulcer may heal with fibrosis and a stenosed calyceal stem is common. The segment of kidney draining into this calyx is frequently also scarred but, as the remainder of the kidney is healthy, a limited resection is appropriate. Partial nephrectomy may also be indicated for a small *renal cell carcinoma*, particularly for a carcinoma in a solitary kidney. Partial nephrectomy is seldom an option in situations with which a general surgeon is faced, but it must occasionally be attempted in trauma when there is an absent, non-functioning or poorly functioning contralateral kidney.

Access for surgery on the *in-situ* kidney is difficult in the depths of an abdominal incision, therefore in elective situations a loin approach is usually favoured. Good hilar access, however, is essential, as temporary occlusion of the renal artery with a soft cross-clamp is necessary during dissection to reduce blood loss. The duration of this occlusion must be minimised, as temporary damage occurs after 15 minutes of warm ischaemia and some permanent loss of function by 30 minutes. Cooling of the kidney increases the parenchymal tolerance of ischaemia. It is most easily accomplished by packing sterile ice slush around the cross-clamped mobilised kidney. However, a significant reduction of temperature in the centre of the kidney is only obtained after 10–15 minutes, during which time surgery cannot proceed without partially removing the ice. Sufficient ice is then removed to enable surgery to proceed.

The arteries and veins to the portion of kidney to be excised may be ligated in the hilum, in which case a colour demarcation between perfused and non-perfused kidney will appear and form a guide to the surgeon in choosing the line of incision. The capsule is incised in the coronal plane over the pole to be removed, and is reflected back as an anterior and posterior flap (Figure 26.5a). The kidney parenchyma is then divided along the line of demarcation, with a hilar occlusion clamp in place. Vessels in the cut surface are secured and ligated prior to release of the clamp. Opened calyces are closed with a continuous absorbable suture (Figure 26.5b). Finally, the capsule is folded back over haemostatic gauze covering the raw surface and loosely sutured.

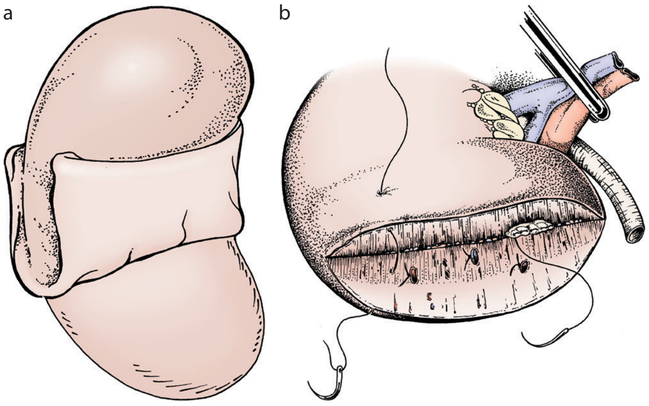

Figure 26.5 *A partial nephrectomy. The vascular pedicle is cross-clamped to reduce haemorrhage. (a) The capsule is incised in the coronal plane and reflected. (b) The parenchyma has been divided as two flaps and parenchymal vessels ligated. The inner suture is closing the opened collecting system before closure of the parenchyma and the capsular flaps.*

SURGERY FOR RENAL CALCULI

Renal stones may be within a calyx or within the renal pelvis. Stones larger than 7 mm in diameter seldom pass spontaneously, but as many are slow growing and may remain symptomless, removal is not always indicated.

- *Lithotripsy*. Most renal calculi can be broken up by shock-waves into fragments of a size that can then pass spontaneously. With larger stones, a double-**J** stent is first passed so that the ureter dilates and fragments of stone can pass more easily.
- *Pyelolithotomy*. The renal pelvis is opened and a stone removed from the pelvis or from an accessible calyx (Figure 26.6). An *extended pyelolithotomy* is a technique in which the plane is developed between the intrarenal pelvis and the overlying renal parenchyma, which is then retracted. The incision into the pelvis can then be extended into the necks of the calyces to remove a staghorn calculus. The incision is closed with absorbable sutures and a ureteric stent left *in situ* for a few weeks. This type of open surgery is very rarely undertaken by surgeons who have access to lithotripsy or to percutaneous pyelolithotomy.
- *Nephrolithotomy*. The incision is made directly through the renal parenchyma into a calyx. Haemorrhage may be brisk.

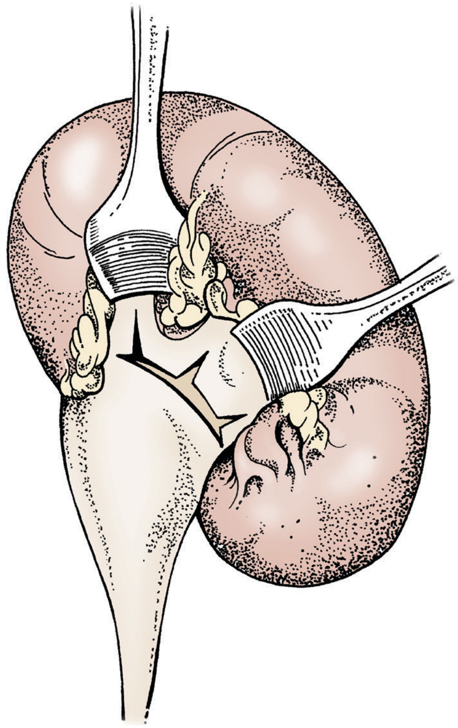

Figure 26.6 *A pyelolithotomy. Retraction to open the plane between renal parenchyma and the intrarenal pelvis allows the incision to be extended into the major calyces.*

- *Total or partial nephrectomy*. A total nephrectomy is the optimum treatment for a non-functioning kidney with a staghorn calculus that is the seat of recurrent urinary sepsis. A heminephrectomy is a good option in a duplex kidney and, occasionally, a partial nephrectomy may be justified if only part of a non-duplex kidney is affected.
- *Minimal-access techniques*. These techniques have greatly reduced the need for open surgery for renal calculi. A nephrolithotomy can be performed percutaneously, and a nephroscope is passed into the renal pelvis. Alternatively, a pyelolithotomy can be performed laparoscopically. It is also possible to reach the renal pelvis ureteroscopically at cystoscopy, and flexible ureteroscopy with laser lithotripsy of the stone has become a standard treatment in most centres of excellence.

Calculi can be removed from the kidney via all these approaches. A *percutaneous nephrolithotomy* has become the treatment of choice for stones in the renal pelvis that cannot be treated solely by lithotripsy. When complete removal at percutaneous nephrolithotomy proves impossible, a staghorn calculus can be debulked and lithotripsy then used to break up remaining fragments.

SURGERY FOR HYDRONEPHROSIS

Hydronephrosis means dilatation of the pelvis and calyces of the kidney. It may be congenital, secondary to a muscular incoordination resulting in a functional obstruction, or it may be due to a mechanical obstruction from a stone, a benign stricture or a tumour. Dilatation can also occur without any evidence of obstruction and is frequently bilateral and associated with hydroureters. This is seen in pregnancy and in ureteric reflux. Differentiation between a dilated and an obstructed collecting system is essential, as a system that is simply *dilated* often requires no intervention. The stagnant urine is, however, susceptible to infection.

An *obstructed* system requires drainage or correction of the underlying pathology, as the increased pressure in the calyces results in a deterioration in renal function, which eventually becomes irreversible. The urgency of the situation depends on the completeness of the obstruction, whether one or both kidneys is/are obstructed and whether there is infection. Bilateral obstruction or obstruction in a solitary kidney is thus of greater urgency, and an obstructed infected kidney (*pyonephrosis*) is an emergency that should be addressed within a few hours (see Chapter 15). Delays of more than a few days should, however, be avoided even in a unilateral obstruction without infection as, especially in complete obstruction, some irreversible damage is already occurring to the kidney.

Nephrostomy

An image-guided percutaneous nephrostomy drainage tube, inserted by a radiologist, is usually the first choice in management of a pyonephrosis. If ultrasound-guided percutaneous drainage is not available, an attempt can be made to drain the kidney endoscopically from below by guiding a catheter up the ureter past the obstruction under image intensifier control, but if this is not possible, an open nephrostomy through a loin approach may be the only option.

Pyeloplasty

An *idiopathic congenital pelviureteric junction (PUJ) obstruction* is secondary to a muscular incoordination at this site, and results in a hydronephrosis. Surgical correction by pyeloplasty is indicated for obstruction rather than for simple dilatation, and careful preoperative assessment of this is essential. The PUJ is divided and reconstructed to form a wider junction with more dependent drainage. The excess renal pelvic tissue is excised. There are multiple refinements of the technique, a simple form of which is shown diagrammatically in Figure 26.7. The operation can be performed as an open or a laparoscopic procedure, with access by a trans- or retroperitoneal approach. Absorbable sutures must be used to reconstruct the junction to avoid the risk of stone formation on the sutures, and a ureteric stent (if used) is left *in situ* for about 3–4 weeks. If there is an abnormal lower pole vessel, the reconstruction is carried out anterior to this. Pelvicalyceal dilation may be little altered at follow-up imaging, but the potentially damaging obstructive element should have been relieved.

Endoscopic balloon dilatation, with or without incision of the PUJ, is a technique with variable long-term results that is less often performed now that the laparoscopic approach has become the standard approach, with results that are equivalent to those of open surgery.

RENAL TRANSPLANTS

A patient with a renal transplant may present to the general surgeon with other unrelated intra-abdominal pathology. The donor kidney may cause problems with diagnosis and with surgical access. The donor kidney has most commonly been placed retroperitoneally in an iliac fossa, and it is turned so that its original posterior surface lies anteriorly. The renal pelvis and the ureter are therefore lying anteromedially and the hilar vessels posterolaterally. The donor renal artery will have been anastomosed end-to-end to the internal iliac artery or, in the case of multiple renal arteries, to the side of the external iliac artery using a donor arterial patch. The donor renal vein is anastomosed end-to-side to the external iliac vein. This anastomotic arrangement may have been contraindicated by atheroma, and alternative donor vessels, including the splenic vessels, may have been used. In children, the transplant may have been placed intraperitoneally, with the anastomoses to the aorta and IVC in the lower abdomen.

URETERIC DAMAGE

Most ureteric trauma is iatrogenic and occurs in either general or gynaecological surgery. In some instances, ureteric resection is inevitable when a ureter is invaded by an otherwise resectable primary tumour. In other instances, inadvertent damage occurs. A ureter may be ligated in error and unless the injury is bilateral or in the only functioning kidney, the surgeon may remain unaware of the problem. A non-functioning kidney may then be an incidental finding some years later, but this can also occur when the ureter has not been ligated or divided. A difficult dissection close to the ureter can cause ischaemic damage with late stricturing and obstruction. Damage to a ureter can also be caused by injudicious use of diathermy, which may not be apparent at the time of surgery.

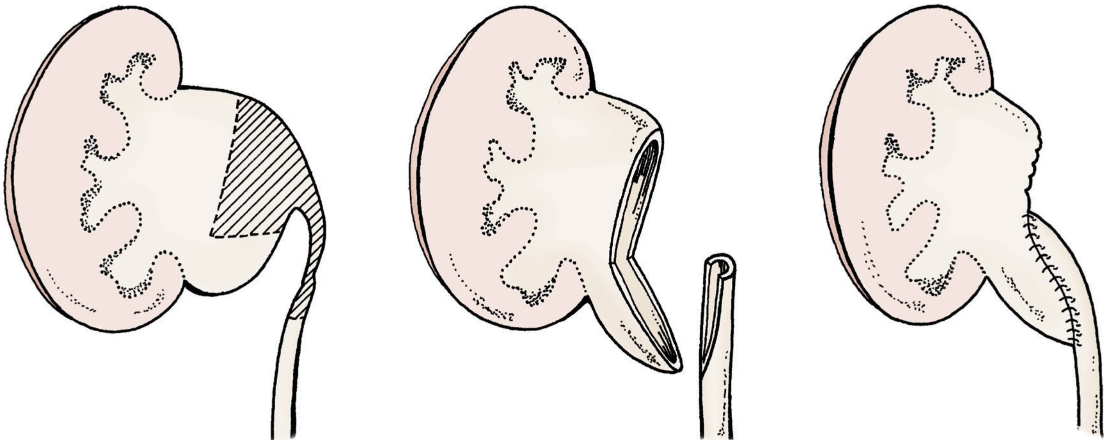

Figure 26.7 *An Anderson–Hynes pyeloplasty. This operation and all the modifications of it are designed to produce a wide, dependent pelviureteric junction for improved drainage.*

When ureteric damage is recognised the surgeon should, if at all possible, seek assistance. It is generally true that any surgeon who causes inadvertent damage to any organ in the body is much less likely to perform a good repair than a colleague who was not involved in the original injury. In the case of accidental damage to the ureter there is often a range of surgical options and, as in all surgery, the choice of procedure may be as important as the technical aspects of the operation that is undertaken. Although the advantages of repair or reimplantation in preserving a functioning kidney are obvious, the surgery will add to the magnitude of the operation and may be an unjustifiable additional procedure in the occasional patient. It is therefore particularly important that when a surgeon causes inadvertent ureteric damage, help and advice are sought from a urological colleague.

Simple repair

Simple repair with interrupted fine absorbable sutures is ideal, but it is only possible when there is minimal loss of tissue (Figure 26.8). The ends should be spatulated to reduce the chance of an anastomotic stricture. A ureteric double-**J** or pigtail stent is inserted both up and down from the point of injury, and should be left *in situ* for 3–4 weeks postoperatively. The guide wire within the stent holds the curled ends straight during insertion. The guide wire is then removed by cystoscopy and the curl returns to the ends. It is these curled portions lying within the renal pelvis and within the bladder that prevent stent migration. It is particularly important with any ureteric stent that the lower end is in the bladder and not curled in the distal ureter, as urine may not drain effectively and the stent will be difficult to remove. If there is any doubt, the position of the lower end is easily checked by cystoscopy. Subsequent removal may be performed with a flexible cystoscope as a local anaesthetic procedure after 4–6 weeks. An IVU is then recommended to assess drainage from the kidney and exclude stricturing at the level of the repair.

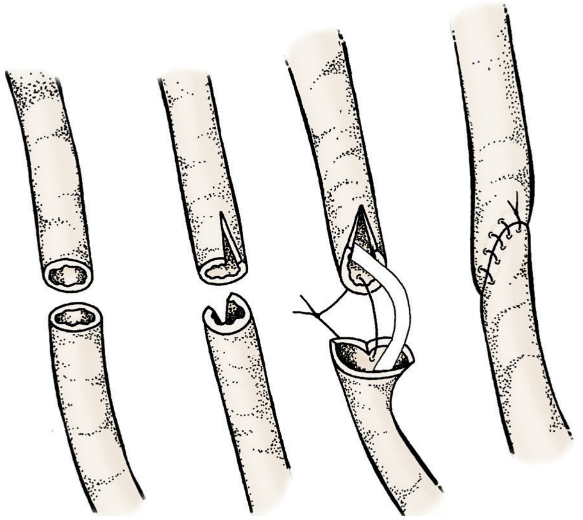

Figure 26.8 *An end-to-end anastomotic repair of a divided ureter. Each end of the ureter is spatulated. This results in a wide, oblique anastomosis, which is carried out with interrupted sutures over a ureteric stent.*

Reimplantation into the bladder

Reimplantation into the bladder is a reconstructive option that should be considered when simple repair is not possible. It is particularly suitable when the ureteric division is close to the bladder. The bladder is opened and the divided ureter spatulated to produce a wider anastomosis with less chance of a stenosis. An oblique tunnel is created through the bladder wall. The anastomosis is performed over a ureteric stent. Mucosal apposition is achieved with fine absorbable sutures, and the bladder muscle wall closed around the ureter with sutures that also tether the muscular coat of the ureter to the bladder (Figure 26.9). Any tension on the anastomosis must

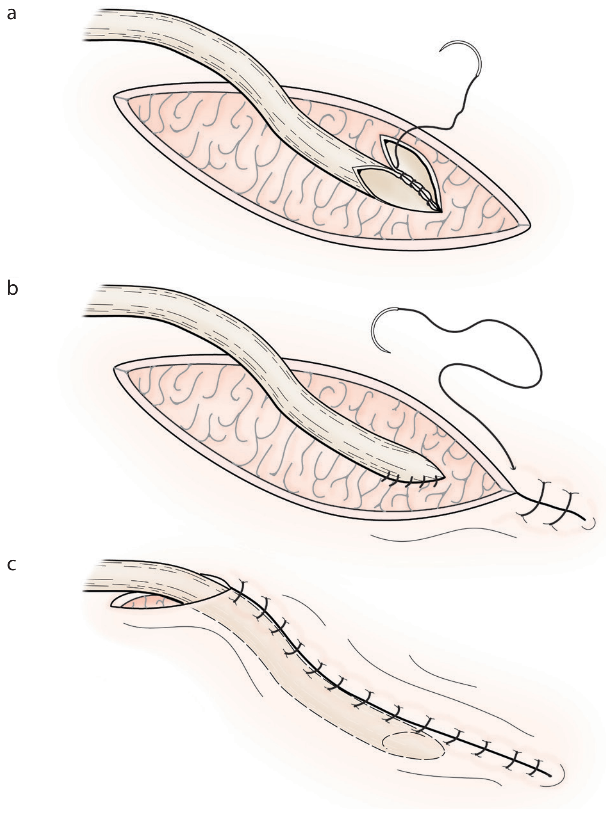

Figure 26.9 *Direct reimplantation of a ureter into the bladder is occasionally possible after a distal injury if there is sufficient length. The creation of an intramural tunnel will prevent reflux. (a) A 2–3 cm incision is made through the muscle coat of the bladder. At one end the incision is deepened through the mucosa. This mucosal incision should create an aperture of similar diameter to that of the spatulated ureter. An anastomosis is performed. (b) The muscle layer of the bladder wall is closed over the ureter. (c) The ureter is lying in an intramural tunnel. The final suture of the muscle layer can also be used to pick up the outer layers of the ureter to reduce any possible traction on the anastomosis.*

be avoided and a *psoas hitch*, in which the bladder is hitched up and fixed to the psoas muscle prior to the reimplantation, is a useful manoeuvre to reduce tension (Figure 26.10). It may help to make reimplantation possible when there is some loss of ureteric length. A flap of bladder (a *Boari flap*) can also be raised and formed into a tubular extension to the bladder, which will reach a surprisingly high level (Figure 26.11). An isolated ileal loop, fashioned to form a ureteric replacement, is another option when there is a long segment of proximal ureter to be replaced, but this is very much a last-resort procedure.

Reimplantation of a ureter into the bladder may also be needed for distal ureteric obstruction and for ureteric reflux, and reimplantation of the ureter forms part of the operation of renal transplantation.

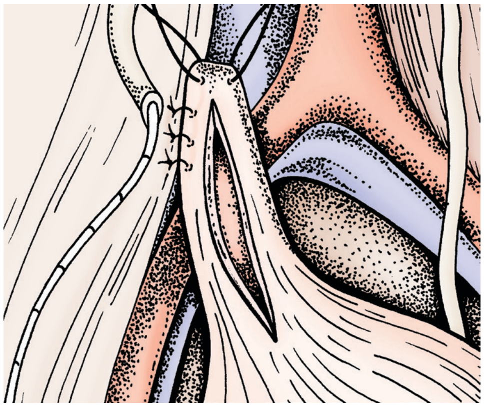

Figure 26.10 *A psoas hitch. The bladder is drawn up, out of the pelvis, and fixed to the psoas muscle. This shortens the distance over which the ureter has to reach and reduces anastomotic tension.*

Ureteroureterostomy

Reimplantation of a divided ureter into the other ureter can always be considered in any situation where direct repair is impractical and the proximal divided end does not reach to the bladder. The proximal portion of the ureter is dissected and freed so that it can be drawn across the midline. The other ureter will also need some mobilisation before a tension-free anastomosis can be achieved. Ureters can be mobilised over a considerable distance without suffering ischaemia, as there is an excellent intramural blood supply. The divided end is spatulated and anastomosed end-to-side into the other ureter, both of which should be stented (Figure 26.12). It must also be remembered that if complications develop, the future of the contralateral previously healthy kidney may also have been jeopardised.

Simple ligation

Simple ligation of the proximal ureter is an option when a segment has been excised that precludes a simple repair and the condition of the patient contraindicates extending the surgery further. The presence of a functioning contralateral kidney must be established. The obstructed kidney atrophies and seldom produces any complications such as urine leakage from the ureteric stump with the development of a ureteric fistula, pain from the initial hydronephrosis or the development of a pyonephrosis. This is in essence little different from the situation where a non-functioning kidney is discovered incidentally some years after pelvic surgery and unsuspected inadvertent ureteric damage or ligation at that operation is the most likely explanation.

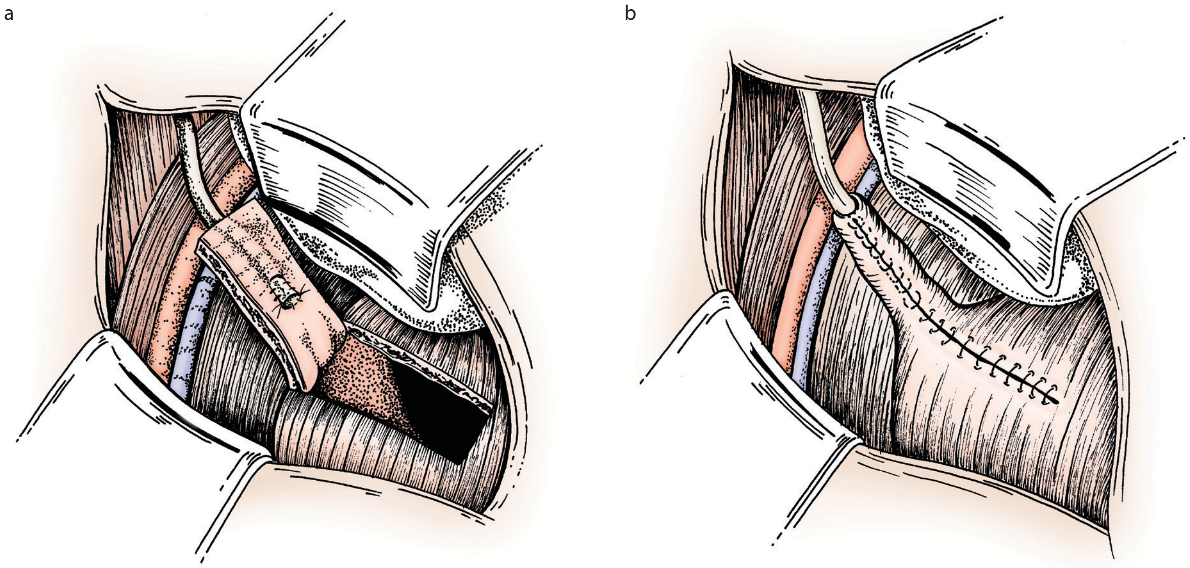

Figure 26.11 *A Boari flap. (a) The bladder must be drawn over to the side of the injury; increased mobility will be obtained by mobilising the opposite side of the bladder. A long flap, with a superolateral base, has been cut from the bladder. The ureter is anastomosed to the flap, with a submucosal tunnel. (b) The flap is tubularised and the suture line continued to close the donor defect.*

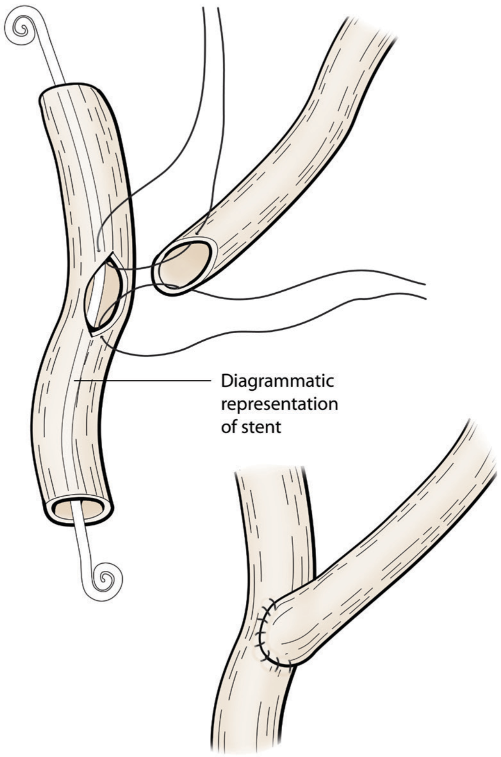

Figure 26.12 *Implantation of a divided ureter into the other ureter is frequently the most satisfactory solution when a ureter has been damaged and length has been lost.*

Nephrectomy

Nephrectomy may occasionally be indicated if ureteric reimplantation is not possible or is contraindicated. Nephrectomy will prevent any complications that might develop in the obstructed kidney if a ureter is simply ligated, but it also increases the magnitude of the surgery.

URETERIC STONE REMOVAL

Ureteric calculi often cause renal colic and temporary partial obstruction before passing spontaneously. Stones more than 5 mm in diameter are less likely to pass spontaneously, but for smaller stones, a short trial of conservative management is usually appropriate. The exceptions are complete obstruction of a solitary kidney or proximal infection. The need for urgent intervention in these situations is discussed above. Ureteric stone removal is more commonly an elective procedure when it becomes apparent that the stone will not pass spontaneously. If obstruction is only intermittent or partial, a delay of some weeks may not be detrimental to renal function.

Open surgery to remove a ureteric calculus is seldom required in urological practice today. Calculi can usually be retrieved or broken up endoscopically, either under image control or with direct vision through a ureteroscope. If this is unsuccessful, it is usually possible to pass a guide wire alongside the stone up to the kidney, and a fine stent can then be introduced over the guide wire. The stent is left *in situ* while further treatment is arranged. For stones in the upper one-third of the ureter, the generally safe option is to push the stone back into the renal pelvis and then to arrange for the patient to undergo lithotripsy. Alternative techniques of endoscopic lithotripsy, and especially direct vision basketry, carry increased risks and are best not attempted outside of a stone management centre. A general surgeon practising in a remote area without access to a urologist, a lithotriptor or any image control may still need to remove a ureteric stone by open surgery.

Open ureterolithotomy

An X-ray should be taken on the operating table before commencing surgery to check that the position of the stone has not altered. The site of the incision will depend on the position of the stone, and the ureter is approached retroperitoneally. Difficulty in finding the ureter can occur if the middle third becomes raised up on the undersurface of the peritoneum. The lower one-third may also be difficult to identify. It may then be easier to identify the ureter at a higher level in the pelvis, or even at the pelvic brim, and then follow it distally.

The ureter is first identified above the stone and a tape passed around it to prevent upward displacement of the stone. The ureter is then followed distally and the position of the stone is recognised by a fusiform swelling of the ureter and confirmed by palpation. A second tape is passed around the ureter below the stone. Two stay sutures are inserted into the ureter at the level of the stone and the stone is steadied between finger and thumb. A longitudinal incision is made through the ureter, between the stay sutures and directly over the stone. The incision begins over the thickest part of the stone and extends upwards to a level just above its upper end (Fig. 26.13). The stone is delivered out through the

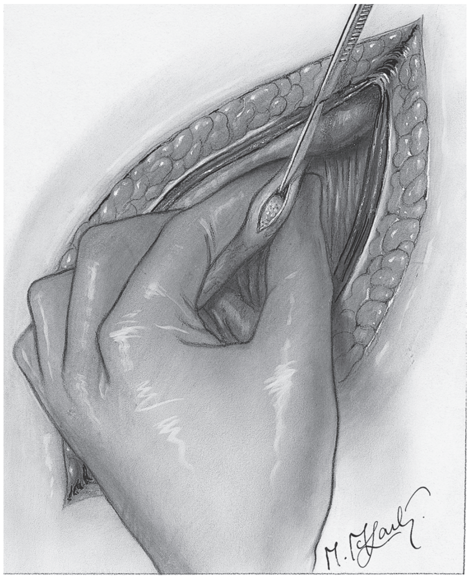

Figure 26.13 *Ureterolithotomy. An original drawing by Margaret McLarty for the first edition of this book published in 1954.*

incision. A ureteric catheter is then passed up and down to wash out any further debris. The incision in the ureter may be repaired with fine absorbable sutures that do not penetrate the mucosa (Figure 26.14). When the ureteric wall is traumatised and oedematous, sutures may be contraindicated and the incision can be left open. A drain should be left to the ureter as, even if it has been closed, urine leakage for a few days is common. If a ureteric stent is employed, it can be removed about 4 weeks later.

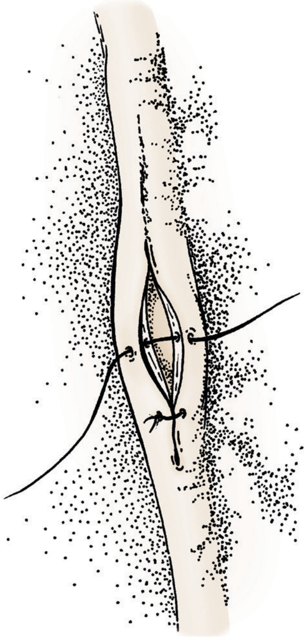

Figure 26.14 *Closure of a longitudinal incision into a ureter has the potential to cause a stricture. Sutures should be loose, well-spaced and ideally should exclude the mucosa.*

URINARY DIVERSION

When there is an intact upper urinary system, but the bladder has been excised or does not function adequately, some form of urinary diversion or reconstruction may be required. Irrepairable damage may have been caused by trauma or by childbirth. Diversion may also be appropriate for a grossly symptomatic bladder as a result of tumour, chronic infection or radiotherapy. It is also an alternative to a permanent indwelling catheter or intermittent self-catheterisation.

Ileal conduits

This is the standard procedure for urinary diversion. The ureters are reimplanted into an isolated small bowel conduit, which is brought out as a permanent urinary stoma. A loop of ileum, at least 15 cm from the ileocaecal valve, is isolated on its mesentery. The loop must be long enough to extend without tension from the midline posteriorly to some 5 cm beyond the site chosen preoperatively on the anterior abdominal wall for the stoma. The ileal mesentery is divided sufficiently to allow the necessary mobility while preserving a good blood supply (Figure 26.15a). The loop will function as a urinary conduit ending as an ileostomy stoma. Small bowel continuity is re-established by an anastomosis in front of the isolated loop.

The ureters are identified and divided as far distally as is practical. Some mobilisation of the caecum and sigmoid colon will usually be necessary at this stage, and it is recommended that an appendicectomy is performed as subsequent surgery for appendicitis may be difficult. The left ureter is then tunnelled medially, under the pelvic mesocolon, to lie

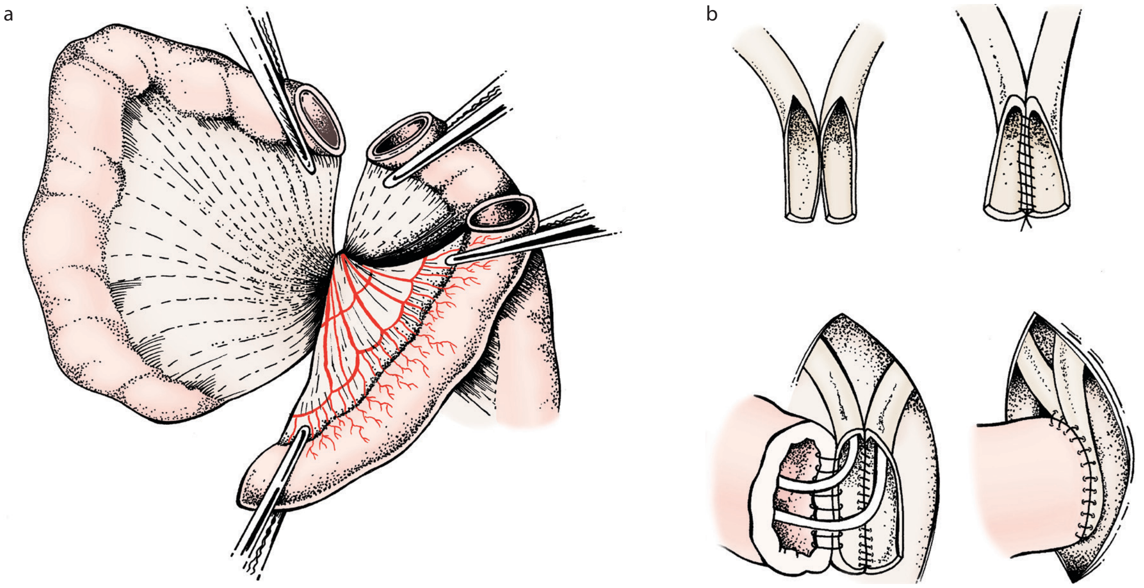

Figure 26.15 *An ileal conduit. (a) A suitable loop of ileum is isolated. The divided ends of ileum will then be brought in front of it for the anastomosis to restore continuity. (b) The ureters are implanted into the proximal end of the loop, the distal end of which is then brought through the abdominal wall as an end ileostomy.*

alongside the right ureter. Both ureters are implanted into the isolated ileal loop and the distal end of this ileal conduit is then brought out, through the abdominal wall, as an ileostomy stoma (see Chapter 22). A variety of methods are employed to perform the anastomoses of the ureters into the ileum. Spatulation of the ureters and accurate mucosal apposition may be important in the prevention of anastomotic strictures, but as reflux is not a problem, an intra-mural tunnel is not required (Figure 26.15b). The anastomoses of ureters to ileum are normally stented for 2 weeks and a loopogram X-ray performed prior to removal to ensure there is no anastomotic leak.

Ureterosigmoidostomy

Ureterosigmoidostomy was a popular solution, as it avoided a stoma, and it is still used in countries where a stoma is unacceptable or where stoma appliances are unavailable. However, there are significantly more complications than with ileal conduits. The rectal contents become fluid and if there is any impairment of sphincter function, some degree of incontinence is inevitable. Ascending infection of the upper renal tract is common, even when the ureter is tunnelled obliquely though the colonic wall to minimise reflux (Figure 26.16). Absorption of urine leads to metabolic disturbances, and urine is carcinogenic in contact with colonic mucosa. This appears to be a particular risk when there is mixing of urinary and faecal contents within the lumen, and patients who have this form of diversion should ideally, after about 10 years, have regular colonoscopy to inspect for malignant lesions near the site of the ureterocolonic anastomosis.

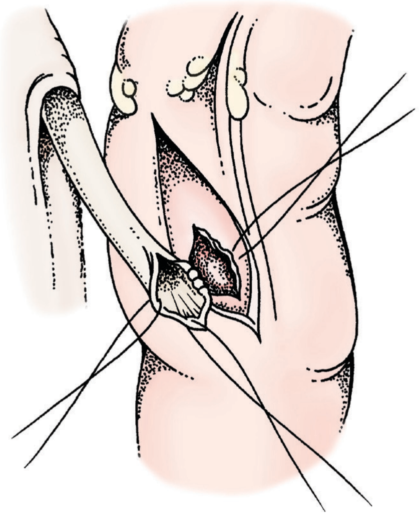

Figure 26.16 *Ureterosigmoidostomy. Accurate mucosal apposition is followed by closure of the seromuscular coat of the colon over the ureter to create a submucosal tunnel. Even with this refinement to prevent reflux, ascending infections are common.*

Cutaneous ureterostomy

Cutaneous ureterostomy is the simplest diversion of the ureter, directly to the skin, as a urinary stoma. There are several disadvantages:

- Two ureters require two separate stomas, as ureteric length is usually insufficient to bring them out together.
- Ureteric length is often still insufficient to reach the skin without tension in a fat patient.
- The stoma is liable to stenose.

Eversion of the stoma to produce a spout similar to an ileostomy and accurate skin mucosal apposition will to some extent prevent stenosis, but this is only possible with sufficient ureteric length. Although a ureterostomy may be useful as a temporary procedure in children, it is generally impractical in adults because of insufficient ureteral length and almost universal stenosis.

CATHETERISATION

Urethral catheterisation

Urethral catheterisation is required for many non-urological surgical patients in the perioperative and early postoperative phases, and the catheter is frequently inserted after induction of anaesthesia. On other occasions, a catheter has to be inserted postoperatively for a patient in urinary retention. As with all invasive urological procedures, antibiotic cover is advisable. A small Foley type catheter (size 12–14) with a 5–10 ml self-retaining balloon is satisfactory. A wider catheter and larger balloon merely cause more urethral trauma and bladder irritation.

Difficulties in *female* patients are usually related to an invisible urethral orifice that has been drawn up the anterior vaginal wall into a stenosed vagina. The position of the urethral orifice can usually be identified digitally as lying in the midline at the junction between the smooth vulval and the corrugated vaginal mucosa, and the catheter is then guided in, on the index finger.

Difficulties in *male* patients are often related to inadequate lubrication and a lack of appreciation of the curves of the male urethra (see Figure 25.16, p. 478). Force is inappropriate, as false passages can be created. If there is difficulty, further trauma to the urethra should be avoided. Either a suprapubic catheter should be inserted or the urethra visualised with a cystoscope. A failed urethral catheterisation at the start of an abdominal operation can wait for a suprapubic catheter to be inserted once the abdomen is open and the bladder has filled.

Percutaneous suprapubic catheterisation

Percutaneous suprapubic catheterisation is an alternative to urethral catheterisation and is relatively simple when there is an enlarged palpable bladder. Local anaesthetic is injected into the midline skin and abdominal wall 5 cm above the pubis. It is advisable to confirm prior to proceeding further that the swelling is indeed a full bladder by aspiration of urine through the needle that was used to introduce the local anaesthetic. A 5- to 10-mm skin and linea alba incision is made, through which a trocar and cannula are introduced into the bladder. The trocar is withdrawn and the backflow of urine can be temporarily controlled with a finger until the self-retaining catheter is inserted down the cannula into the bladder. The proprietary suprapubic catheterisation sets have a splittable cannula, which separates into two portions, making removal easier once the catheter is in place.

A similar technique can be used to insert a suprapubic catheter into a partially filled bladder during a laparotomy. If the bladder has not filled sufficiently, sterile saline or water is injected via a bladder syringe into the external urinary meatus. The surgeon inserts one hand into the pelvis behind the bladder. A small incision is made laterally in the lower abdomen, taking care to avoid the inferior epigastric vessels. The trocar and cannula are introduced through this incision and advanced posteriorly and caudally through extraperitoneal tissue until the bladder wall is breached. Advancement through the bladder wall is aided by the support of the surgeon's hand behind the bladder. A suprapubic catheter has advantages over urethral catheterisation after pelvic surgery, as many elderly male patients are slow to regain bladder function. At 7–10 days postoperatively, the suprapubic catheter is simply clamped, and unclamped if necessary. This is preferable to repeated recatheterisations after failure to void.[3]

Difficulty in inserting a suprapubic catheter is usually due to a poorly filled bladder. In the anaesthetised patient the bladder can be filled from below by insertion of the nozzle of a syringe into the meatus and injection of 200–300 ml of sterile water up the urethra.

Suprapubic cystostomy

Percutaneous establishment of a suprapubic catheter is not possible when there is an impalpable shrunken bladder that will not distend. The catheter has to be placed in the bladder by an open dissection. The pre-peritoneal space is entered through a suprapubic incision, the bladder is identified and a small incision is made into it through which the catheter is advanced. The bladder is closed around the catheter.

Mitrofanoff continent cystostomy

A Mitrofanoff continent cystostomy creates a continent, but catheterisable, stoma into the bladder. It has proved a good alternative to ileal conduit diversion in children with neuropathic bladders. The appendix on its intact mesentery is removed from the caecum and reimplanted into the bladder in such a way as to prevent reflux. The appendix tip is brought out on the abdominal wall as a small stoma, which can be catheterised by the patient several times a day (see also Chapter 23).

ENDOSCOPIC PROCEDURES

The most common urological approach for bladder and prostate pathology is transurethrally with a resectoscope. Most general surgeons will no longer consider this as part of their practice and certainly they are unlikely to be aware of the most recent advances in endoscopic urology. However, a general surgeon practising in a small hospital, with no emergency urological service, may have to pass a cystoscope to irrigate the bladder for clot retention. A resectoscope has the added advantage that diathermy coagulation of a bleeding area or resection and coagulation of a tumour is then also possible. A three-way urethral catheter is then inserted and irrigation of the bladder continued to prevent further clot formation.

Cystoscopy

Cystoscopy is the inspection of the inside of the bladder by the passage of a cystoscope through the urethra.

Flexible fibreoptic cystoscope

A flexible fibreoptic cystoscope, when well-lubricated with local anaesthetic gel, can be passed with minimal discomfort in patients of either sex. The passage through the urethra is under direct vision and excellent views of the bladder and urethra are obtained. The working channels, however, are small and it is not a practical instrument through which to irrigate intravesical clots or to undertake any major operative procedure. It is therefore an instrument used mainly for diagnosis.

Rigid cystoscope

A rigid cystoscope is best passed with the patient in the lithotomy position, but with the hips only slightly flexed (Figure 26.17a). The rigid instrument can be passed easily in the female, but in the male the angulations of the urethra make some form of general or regional anaesthesia more appropriate. Blind passage of a cystoscope or urethral dilator risks iatrogenic injury, especially if the angulation of the male urethra is ignored. Blind insertion is commenced with the penis held vertically and the angled tip of the obturator orientated so that it will enter the membranous urethra as the cystoscope is advanced. As the tip is felt to pass through the prostate, the cystoscope is progressively lowered towards the horizontal as the bladder is entered. A cystoscope should routinely be passed under direct vision, using a 0- or 30-degree lens, so that the urethra can be inspected during insertion. The flow of irrigation fluid holds the urethra open ahead of the scope, and minimises trauma. Telescopes for

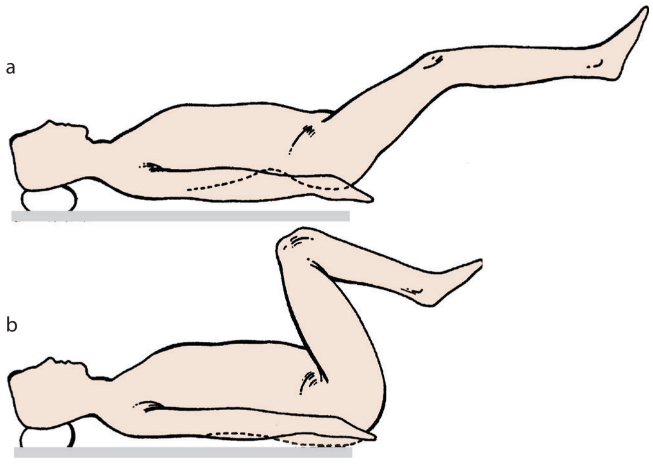

Figure 26.17 *(a) The optimal position for urological procedures. (b) This position is more satisfactory for anal surgery, but in males a rigid cystoscope passed with the patient in this position puts unnecessary pressure on the urethra.*

cystoscopy have a choice of angle of view. The 0-degree telescope is most appropriate for viewing the urethra, but the 90-degree telescope may be required to see the area of bladder behind a large prostatic indentation. In addition to the telescope and the irrigation channel, it is possible to pass forceps for biopsy or instruments for grasping or crushing a calculus. Ureteric catheters or stents can be passed up the cystoscope and into the ureteric orifices.

Resectoscope

A resectoscope is a rigid cystoscope with an insulated sheath, which is necessary when endoscopic resection with diathermy is to be undertaken.

Ureteric cannulation

When a ureteric catheter is to be passed, a deflecting mechanism may be necessary. This has two channels through which the ureteric catheters are advanced and, at the distal end, a platform that can be elevated to guide the tips of the catheters into the ureteric orifices. The passage of a Dormia basket up a ureter to retrieve a distal ureteric calculus follows similar principles. The double-**J** or pigtail stent illustrated in Figure 26.12 is passed in a similar manner to a ureteric catheter, but over an initial internal guide wire that holds the stent straightened until it is in position. The guide wire is then withdrawn and the two ends of the stent curl again, with one curl in the renal pelvis and one in the bladder.

Ureteric cannulation is usually undertaken under continuous X-ray monitoring. The ureteric catheter, stent or instrument is radiopaque and, in addition, small boluses of contrast material injected up a ureteric catheter outline the ureter, define its course and will demonstrate any perforation with contrast extravasation. The passage of a rigid or flexible ureteroscope up a ureter allows endoscopic inspection of the ureter but, as the lumen is small, operative procedures are restricted. Ureteric stones can be disintegrated under direct vision using the fine wire of the electrohydraulic lithotripter, ultrasound or laser.

Transurethral resection: general principles

Endoscopic excision of bladder tumours and of benign and malignant prostatic tissue forms a major part of urological practice.[4] For any endoscopic diathermy an insulated cystoscope sheath (resectoscope) is required. Through this is passed the working element, which can be moved backwards and forwards within the sheath during resection. The diathermy loop, which may be either a wire for cutting or a ball for coagulation, is passed down a channel in the working element, into which the telescope is also incorporated. Today, most resections are carried out with the surgeon watching a video camera image on screen.

Saline should not be used as an irrigating fluid as it forms an electroconductive solution that interferes with the diathermy current. Sterile water is also contraindicated when there is a significant danger of it entering open veins, with the risk of haemolysis and death. This is of particular importance in prostatic resection. Glycine (1.5%) is a widely used irrigating fluid for resection, but metabolic problems including low sodium levels can be caused following the absorption of large quantities during a prolonged resection (transurethral resection syndrome).

TRANSURETHRAL RESECTION OF BLADDER TUMOURS

The mainstay of surgical management of superficial bladder cancer remains endoscopic resection of the tumour and long-term endoscopic surveillance for early diagnosis and treatment of further transitional cell tumours. Intravesical cytotoxic chemotherapy and intravesical BCG immunotherapy are used in a variety of regimes to reduce recurrences. Coagulation, without resection, may be adequate for multiple small recurrences of superficial bladder tumour, but histological evidence of the degree of differentiation and the depth of invasion is not obtained. This is important in the overall management, as for deeply invasive tumours endoscopic resection alone is insufficient. A total cystectomy or radiotherapy, with or without neoadjuvant chemotherapy, still offers the prospect of cure in these cases, and palliative radiotherapy also has a role in local control. Palliative resection of advanced tumours can be effective in reducing haemorrhage. Any surgeon who undertakes the management of transitional cell carcinoma of the bladder should be familiar with the evidence base for the use of mitomycin C and BCG in the prevention and management of these tumours, and also understand the indications for cystectomy, radiotherapy and chemotherapy.

Operative procedure

Initially, a cystoscopy is carried out to confirm the diagnosis. If there is a need for resection, the urethra should be calibrated and a urethrotomy performed if the larger diameter of the resectoscope will make it too tight a fit. The external urethral meatus is frequently the narrowest portion of the urethra.

The tumour is resected down to the bladder wall and the tissue sent for histological examination. Further tissue, to include muscle, is then resected from the base of the tumour, and is sent separately for histology to provide information for staging the disease. Haemostasis is obtained. Except when small tumours are resected, it is usual to drain the bladder with a three-way irrigating catheter.

When resecting laterally, the electric current may stimulate the obturator nerve, causing the patient to 'kick'. Resecting in such a position is best carried out with a relatively empty bladder and, if necessary, the anaesthetist may need to paralyse the patient with a depolarising agent. Access to tumours in the vault may be difficult, and such resection may be facilitated by placing the patient in a head-down position with an assistant applying suprapubic pressure.

Extraperitoneal perforations, which may be deliberate with extensive tumour resections, will require catheter drainage for 10–14 days. Intraperitoneal perforations often require laparotomy and formal closure.

TRANSURETHRAL RESECTION OF THE PROSTATE

Transurethral resection of the prostate is the standard operation for urinary retention or severe urinary symptoms attributable to prostatic obstruction. A retropubic prostatectomy will usually be a safer option in the hands of a general surgeon without endoscopic expertise, and is a suitable alternative except for obstruction from a malignant prostate.

It may not be necessary to resect small obstructed glands as they can be treated by a bladder neck incision. This is a full-thickness cut made from below one of the ureteric orifices, through the prostatic capsule to the level of the verumontanum. After this procedure the bladder neck can be seen to 'spring open'. However, larger prostates will need to be resected.

Operative procedure

The object of the resection is to remove the central adenomatous tissue, while preserving the prostatic capsule. For full operative details the reader should refer to a standard text on transurethral resection.[4] The resectoscope is passed as for the resection of a bladder tumour. Different surgeons then proceed in a variety of ways. One method is to start the resection at around the 5 o'clock position, cutting a groove from the bladder neck down to the verumontanum, and deepening the channel until the more fibrous prostatic capsule is seen. A similar groove is cut at the 7 o'clock position, and the whole of the posterior middle lobe can be resected. Haemostasis is secured with the patient slightly head-down, and a similar groove is cut anteriorly at 12 o'clock to the level of the verumontanum, again exposing the capsule. The channel is widened on one side and, by resecting at the level of the capsule, the lateral lobe can be detached from the capsule and it will fall medially. When the majority of the lobe has been detached it can be resected piecemeal, and capsular haemostasis obtained. A similar procedure is then carried out on the opposite side. The most important point in the technique is to ensure haemostasis after each stage of the procedure. If vision is lost, it may be safer to stop resecting, insert a catheter and, if necessary, repeat the resection some months later.

At the end of the operation, after haemostasis has been checked, the bladder is drained with a stiff 22/24 three-way irrigating catheter and irrigated with normal saline.

OPEN BLADDER AND PROSTATIC SURGERY

The bladder and prostate are usually approached through a suprapubic incision, and the dissection is in the preperitoneal plane. The general surgeon, however, is more likely to be involved with the bladder from within the peritoneal cavity when it is involved in trauma or invaded by intestinal pathology.

Trauma

Bladder trauma can be divided into intraperitoneal and extraperitoneal rupture. *Cystography* may be useful in diagnosis. Intraperitoneal rupture requires a laparotomy and closure of the bladder wall with absorbable sutures, followed by a period of at least 10 days during which the bladder undergoes continuous catheter drainage to allow healing. Extraperitoneal rupture can usually be managed by catheter drainage alone. However, it may well be associated with major pelvic trauma, and suprapubic urinary drainage may then be more appropriate. Injuries to the proximal urethra are discussed in Chapter 25. Iatrogenic trauma is most often in the form of an inadvertent entry into the bladder when opening the abdomen or during pelvic dissection. Closure of the opening with absorbable sutures and urethral drainage are all that is required.

Vesicovaginal fistulae

The most common cause of these fistulae is a childbirth injury. The repair is described in Chapter 27.

Bladder calculi

Removal of calculi that are too large to be removed endoscopically is a straightforward procedure through a preperitoneal suprapubic approach. In adults, bladder calculi are usually associated with bladder outflow obstruction or a large residual urine volume, and the underlying cause should be addressed. Bladder calculi in young children are common in some parts of the developing world, and this is a condition for which a general surgeon may have to operate. After removal of the calculus the bladder is closed and drained as described above.

Partial cystectomy

Partial cystectomy is an operation that is probably performed more frequently by general surgeons than by urologists. A disc of bladder may be excised, which is adherent to, and possibly invaded by, a sigmoid colon cancer. A diverticular mass may also be densely adherent to the bladder, but can often be 'pinched off'. However, at the time of surgery, malignancy may still be suspected and a disc of bladder is then often resected *en bloc* to avoid opening potential tumour planes and compromising a curative resection. Both sigmoid colon malignancy and diverticular disease may be associated with a colovesical fistula. The main concern is the proximity of the involved bladder to the trigone and the ureteric orifices. A preoperative cystoscopy will often demonstrate the area of tethered or inflamed mucosa. If it is close to the trigone, or difficulty is anticipated, ureteric catheterisation will make identification of the ureters easier during the dissection. After excision of a disc of bladder, the bladder wall is closed and drained by a catheter until healing is sound. The more distal rectovesical fistulae, which are associated with locally invasive rectal or bladder cancer, will commonly involve the bladder trigone. A colorectal surgeon operating on a patient with a high rectal cancer with a fistula into the bladder should not anticipate that a partial cystectomy will be an option, as the ureteric orifices will almost certainly also be involved. The surgical options will be either a palliative colostomy to reduce faecal contamination of the urinary tract or a combined operation with a urologist to perform a pelvic exenteration and urinary diversion.

Total cystectomy

Total cystectomy is the best potentially curative option in some patients with locally invasive bladder cancer. However, in truly advanced bladder malignancy it has little place, as distant metastases are usually present. It is also indicated in patients who present with superficial bladder cancer associated with widespread carcinoma in situ who fail to respond to intravesical immunotherapy or chemotherapy. Intravesical BCG may reverse the changes in the transitional epithelium, but maintenance treatment and careful surveillance with multiple biopsies are important. If no action is taken, progression to invasive tumour is almost inevitable. The following is a summary of the operation, but a surgeon embarking on this procedure will require more operative detail.

Operative procedure

At laparotomy, the extent of the disease is ascertained and, if still thought suitable for operation, the initial procedure is bilateral dissection and removal of the common iliac and obturator lymph nodes. The vas deferens in the male and obliterated umbilical vessels are divided, and the ureters identified at the pelvic brim and dissected free down to the bladder, dividing the superior vesical vascular pedicles laterally. Posteriorly, the peritoneum in the rectovesical pouch is divided, and the plane between the rectum and Denonvillier's fascia posteriorly and the bladder, seminal vesicles and prostate anteriorly in the male is opened. The ureters are divided as low down as is convenient.

The anterior surfaces of the bladder and prostate are exposed and the endopelvic fascia, attaching the prostate to the back of the pubis, is divided. The dorsal venous complex at the apex of the prostate can be divided between sutures, exposing the urethra. This (and the *in-situ* urethral catheter) is then divided, and haemostasis of the distal end and the dorsal venous complex can be achieved by sutures. The bladder and prostate can then be removed *en bloc* by division of the inferior vesical plexus. In the female, total cystectomy is combined with a hysterectomy.

The standard urinary diversion is via an ileal conduit. Today, for younger patients, bladder reconstructive procedures are feasible.

Total cystectomy also forms part of the total pelvic exenteration that is sometimes indicated for a locally advanced rectal, cervical or uterine cancer. The urologist, general surgeon and gynaecologist may operate together in such cases. The dissection is modified so that planes between the bladder and adjacent involved organs are not breached.

Bladder reconstruction

An isolated segment of bowel can be used to replace part, or all, of the bladder. The complete replacement of the bladder with a neobladder fashioned from an ileal or colonic loop can provide good functional results when the surgery is undertaken by urologists with a special interest. The neobladder is created from a detubularised loop of ileum or colon, which is isolated from the gastrointestinal tract in a similar manner to that described for an ileal conduit. The ureters are implanted into the neobladder, which is then anastomosed to the proximal urethra or trigone.

A detubularised bowel loop can also be used to augment a small shrunken bladder. The bladder is split coronally to receive the bowel loop, which augments the bladder volume.

Retropubic prostatectomy

In benign pathology, the enlarged adenoma within the prostate can be removed at open surgery by either a retropubic or a transvesical route. Only the retropubic approach has remained in common use, and even the indications for this method are dwindling as transurethral resection, laser ablation and enucleation have become the standard treatment in skilled hands for even very large prostates.

Operative procedure

A cystoscopy should be performed before a retropubic prostatectomy to exclude any associated bladder pathology. The patient is then placed supine and the table tilted head-down. The extraperitoneal plane is entered via a lower midline or transverse suprapubic incision (Figure 26.18a). The wound is held open with a self-retaining retractor and pressure is exerted on the bladder with a swab held in forceps. This tilts the prostate away from the pubis and exposes the fat on the surface of the prostatic capsule. The vessels within this fat must be secured with coagulation diathermy or ligation so that the fat can be cleared to expose the capsule and the fibres of the puboprostatic ligaments meeting in a **V** at the bladder neck. The prostatic capsule will be opened transversely a centimetre or two below the bladder neck. Deep absorbable stay sutures are placed above and below the point chosen for this incision. These sutures are tied to reduce bleeding from the capsule (Figure 26.18b). A generous transverse incision is then made through the prostatic capsule to expose the white surface of the adenoma.

The anterior commissure of the prostatic lobes is then opened digitally to enable the surgeon's index finger to enter the prostatic urethra and feel the verumontanum and the prostatic adenoma from within the urethra. Digital pressure with the index finger posterolaterally just above the level of the veromontanum will produce a split in the urethra. This split can be extended around the apex of the prostatic adenoma by further digital pressure, and the remainder of the plane between the adenoma and the prostatic capsule is then freed in a similar manner. The adenomatous lobe is then delivered out of the capsule and its remaining attachment at the bladder neck divided with scissors. The procedure is then repeated on the other side.

The prostatic cavity is then packed with swabs and attention turned to the middle lobe. The top of the middle lobe is grasped in tissue forceps and drawn forwards, while a small swab on a stick, placed in the base of the bladder, is drawn anteriorly. This will demonstrate the interureteric bar and the ureteric orifices. The middle lobe is then resected. A diathermy incision is commenced in the midline behind the middle lobe (Figure 26.18c). The incision is carried anterolaterally in front of each ureteric orifice to the bladder neck. The posterior prostatic urethra can then be divided with scissors just above the level of the verumontanum and the enucleation of the middle lobe completed.

Haemostasis can be improved by suturing the posterior bladder mucosa to the bladder neck with an absorbable suture. The first two stitches of the capsular closure are inserted beyond each end of the capsular opening. A strong absorbable material is used and a deep bite taken. Tying of these stitches reduces the prostatic capsular bleeding, while the prostatic cavity is checked for bleeding points that can be sealed with diathermy coagulation. Finally, closure of the capsule is completed from both ends with a haemostatic continuous suture. Pressure on the bladder, similar to that used before the capsule was opened, will improve access for closure. A rigid plastic 22/24 three-way catheter is guided into the bladder before the capsular closure is completed. The tip will tend to catch on the bladder neck, and has to be lifted forwards. After capsular closure, the catheter balloon is inflated with 30–40 ml of water and the bladder filled to check for leakage at the closure site. Additional sutures can be placed if there is any leakage or continuing suture line haemorrhage. When there is excessive bleeding from the prostatic bed, it may be advisable to place an additional suprapubic catheter through the anterior wall of the bladder before the capsular closure is complete. This can be used for extra irrigation.

A retropubic drain is advisable for the first 48 hours. The urethral catheter is placed on continuous irrigation and

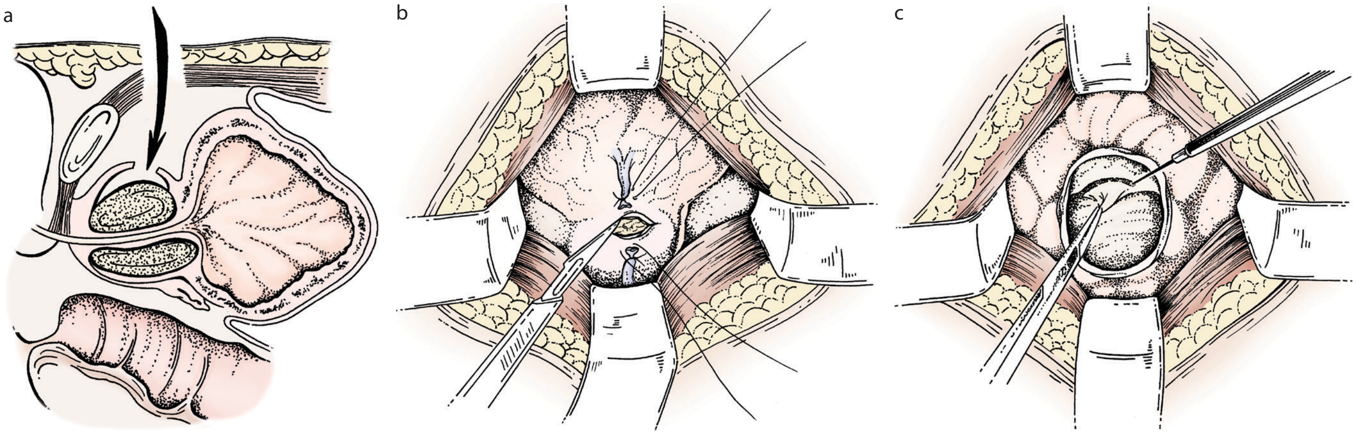

Figure 26.18 *Retropubic prostatectomy. (a) The pre-peritoneal space is entered suprapubically. (b) The anterior prostatic capsule is completely cleared of fat and veins, and is incised transversely between stay sutures. (c) The bladder neck has been grasped with tissue forceps and the middle lobe of the prostate is excised. Identification of the ureteric orifices is important at this stage to avoid damaging them when the bladder neck suture is placed.*

continuous drainage. Irrigation can be stopped when bleeding reduces and no further clots are in danger of blocking the catheter. The catheter can normally be removed after around 5–6 days. A blocked catheter requires saline irrigation with a bladder syringe. Occasionally, a patient has to be returned to theatre for excessive bleeding. A resectoscope is passed, the clot washed out and bleeding points sought, but seldom are precise points found. Fortunately, even if no bleeding point is identified, the bleeding usually settles after such a wash-out.

Radical prostatectomy

The diagnosis and management of prostate cancer are major aspects of urological practice, but is outwith the scope of a general surgical text. Biochemical screening, in conjunction with prostatic biopsy, can be used to identify men with presymptomatic early prostate cancer. In those with a life expectancy of over 10 years, radical retropubic prostatectomy is now one of the treatment options. Radical prostatectomy is only an option in early disease and, even in expert hands, carries a significant morbidity of incontinence and impotence.

Radiotherapy is another potentially curative option in localised prostate cancer. Medical castration therapy with hormone manipulation is an important treatment both for the elderly patient with a limited life expectancy and for those with metastatic disease, in whom it can abolish the pain from metastases. In countries with limited healthcare resources, bilateral orchidectomy remains a useful alternative to medical castration. A transurethral resection of the malignant prostate may be required for outflow obstruction.

SURGERY OF THE URETHRA

For details, see Chapter 25.

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27

GYNAECOLOGY AND OBSTETRICS FOR THE GENERAL SURGEON

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Not infrequently, the general surgeon, when performing a laparotomy, encounters an unexpected gynaecological condition, the correct management of which may cause some doubt and anxiety. The surgeon can usually call on the assistance of a gynaecological colleague, and should do so if at all possible. However, on occasion, and without access to a gynaecological opinion, the general surgeon must accept responsibility for deciding what, if any, operative procedure is indicated and for mastering the techniques required. It is mainly for such guidance that this chapter is written.

There are some general surgeons working in small remote hospitals who are offering a simple, but reasonably comprehensive, obstetric and gynaecological service. This chapter cannot cover their operative surgical needs, and further training and reading are recommended.[1–4] There are, however, other surgeons whose normal practice does not include obstetrics or gynaecology but who may be summoned unexpectedly as the only available surgeon to operate in a life-threatening obstetric or gynaecological emergency. These situations are covered briefly in the following text.

Many of the scenarios outlined below would ideally be treated by less invasive procedures if a preoperative diagnosis could have been established and if the necessary equipment and expertise were available. For example, many ectopic pregnancies can be managed medically or laparoscopically, and massive obstetric haemorrhage may sometimes be best controlled by embolisation of pelvic vessels. However, on the occasions when a general surgeon has to be involved in an obstetric or gynaecological emergency, these techniques are seldom an option.

SURGICAL ANATOMY

The female genital tract, which lies between the rectum and the bladder, is confined to the pelvis except in pregnancy.

THE VAGINA

The vagina lies in close proximity to the bladder and urethra anteriorly and to the rectum and anus posteriorly. Below the peritoneal reflection, the vaginal and rectal walls are separated by the rectovaginal septum, and above the peritoneal reflection by the rectovaginal pouch (Pouch of Douglas). The vault of the vagina is invaginated anteriorly by the uterine cervix, which divides the vault into anterior, lateral and posterior fornices. The ureters and the uterine arteries are closely related to the lateral fornices.

The *labia majora* skin folds lie on either side of the vaginal introitus, with the smaller *labia minora* medially. Flanking the vaginal introitus are *Bartholin's glands* and their ducts, which open into the vagina distal to the hymen.

THE UTERUS

The uterus lies between the bladder and the rectum, as a mainly intraperitoneal organ. Anteriorly, the peritoneum is reflected onto the upper surface of the bladder from the shallow *uterovesical pouch*; posteriorly, it sweeps downwards over the posterior fornix and then is reflected onto the anterior aspect of the mid-rectum, thus forming the *rectovaginal pouch.* The uterine *cervix* is below the peritoneal reflection. The supravaginal portion of the cervix is related to the bladder anteriorly, to which it is connected by some loose fibrous strands.

- The *Fallopian (uterine) tubes* lie along the upper free border of the broad ligament, the upper part of which is the *mesosalpinx.* Medially, the tubes traverse the uterine wall to open into the upper angle of the uterine cavity. The lateral ends emerge from the posterior layer of the broad ligament and divide into multiple finger-like processes termed *fimbriae.* This open lateral end is in communication with the peritoneal cavity and lies close to the ovary.
- The *broad ligament* is a fold of peritoneum that stretches from the lateral wall of the uterus to the pelvic sidewall (Figure 27.1). Its upper free border contains the uterine tube in its medial four-fifths; its lateral one-fifth, containing the ovarian vessels, constitutes the *infundibulopelvic ligament.* The uterine vessels lie between the layers of the ligament, first along its base and then close to its attachment to the side of the uterus.
- The *round ligament* raises a ridge on the anterior surface of the broad ligament as it passes from the uterus to the deep inguinal ring.

THE OVARY

The ovary lies on the lateral part of the posterior surface of the broad ligament, to which it is attached by a small fold of peritoneum, the *mesovarium.* Apart from its mesovarian attachment, the ovary is devoid of peritoneal covering. A normal ovary is 3–5 cm in length. It is greyish-white in colour, but its size, shape and surface can vary considerably throughout the menstrual cycle. In pre-pubertal girls it is smooth, but following puberty the surface becomes wrinkled and scarred, and it may contain several or single cysts.

- The *ovarian ligament* attaches the ovary to the uterus and raises a small ridge on the posterior surface of the broad ligament.
- The *infundibulopelvic ligament* attaches the ovary to the pelvic sidewall and carries the ovarian vessels.

VESSELS

The female genital organs have a rich blood supply, and in pregnancy the uterine arteries enlarge substantially.

- The *uterine artery* arises from the anterior division of the internal iliac; it runs forward to the base of the broad ligament and then medially within it above the lateral fornix of the vagina, where it crosses the ureter 1–2 cm lateral to the supravaginal part of the cervix; finally, it runs upwards along the lateral margin of the uterus, to which it gives numerous branches, including one to the uterine tube.
- The *ovarian artery* arises from the aorta, a little below the renal artery, and runs down the posterior abdominal wall; it then passes forwards and medially to reach the ovary via the infundibulopelvic ligament.

ANTERIOR PERINEAL PROBLEMS

Bartholin's abscess

A Bartholin's gland may distend and form a cyst if the duct becomes blocked. An infected cyst forms a painful abscess. The operation of choice is that of marsupialisation of the gland, and this can be performed under local anaesthetic. Marsupialisation is the preferred technique as it leads to the preservation of the gland's lubricating function, and if an opening of adequate size is created, there is a low risk of recurrence.

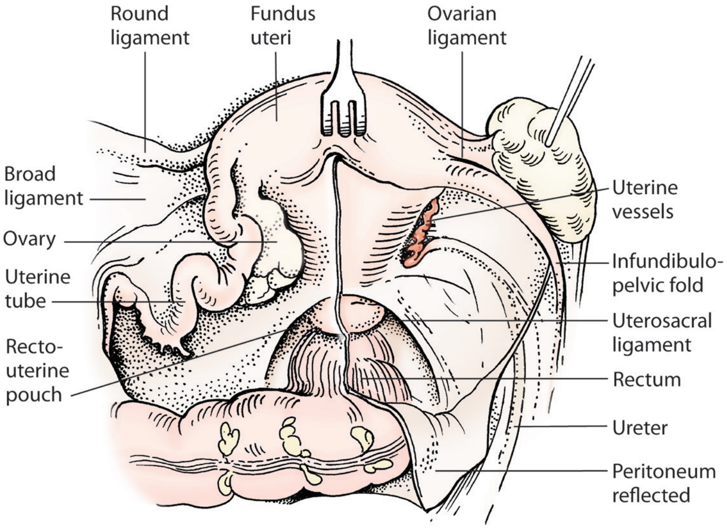

Figure 27.1 *Anatomy of the female pelvis, viewed from above at laparotomy.*

Operative procedure

An elliptical incision of 1–2 cm is made over the convexity of the abscess on the hymenal side, so that the opening will drain into the vagina. The skin ellipse is excised, after which a similar ellipse is excised from the cyst wall and the abscess drained. It is preferable, but not always possible, to excise these two ellipses separately. A series of fine absorbable interrupted sutures is placed around the circumference to include both layers, forming an elliptical opening. The large size of the opening looks alarming initially, but once all inflammation has settled the final diameter is much smaller.

Vesicovaginal fistulae

These fistulae are common in areas where skilled intervention is unavailable during an obstructed labour. The pressure of the fetal head against the pubic symphysis causes ischaemic necrosis of the vaginal and bladder walls before finally, after several days of obstructed labour, a stillborn baby is delivered. Although repair should rightly be viewed as a specialised urogynaecological challenge, in practice many of these injuries are repaired by generalists, often in relatively remote hospitals. Expertise has been developed in the Addis Ababa Fistula Hospital and their training courses and video are recommended to surgeons wishing to undertake these repairs.[5] No specialised equipment is needed.

Operative procedure

Most repairs are performed from the perineum. A urethral catheter is passed and will be left on free drainage for 2 weeks postoperatively while the bladder heals. The fistula may be close to the ureteric orifices, which must be identified and preserved. The plane between the bladder and vagina is infiltrated with a dilute adrenaline solution and the two organs are separated by a combination of sharp and blunt dissection. Extensive mobilisation of the tissues is required. The bladder and vagina are repaired as separate layers with absorbable sutures. A Martius flap interposition (see Chapter 24, p. 449) has proved valuable in bringing well-vascularised tissue between the two suture lines when tissue loss has been significant.

Perineal third-degree tears with anal sphincter disruption

The repair of these obstetric injuries to the anal sphincters is discussed in Chapter 24.

Rectocoeles

Rectocoeles are commonly the result of obstetric damage to the rectovaginal septum. Many require no operative intervention, but those that come to surgery may be operated on by either gynaecologists or coloproctologists. The surgical options are discussed in Chapter 24.

CONDITIONS AFFECTING THE FALLOPIAN TUBE

Salpingitis

Pelvic peritonitis from salpingitis may be indistinguishable preoperatively from pelvic peritonitis secondary to appendicitis. Even after the abdomen has been opened, the diagnosis may initially still be in doubt. Fallopian tubes lying within an appendix abscess will be inflamed and an appendix lying within the pus of a severe salpingitis will show serosal inflammation (see Chapter 22). Once the diagnosis of salpingitis is established, only a bacteriological swab and peritoneal toilet are required before closure of the abdominal incision and the instigation of antibiotic therapy. An endocervical swab should also be taken to check for *Chlamydia*. Salpingitis in a scarred blocked tube may form a pyosalpinx; this trapped pus requires drainage either by simple incision or, preferably, by a salpingectomy.

Ruptured ectopic pregnancy

Most ectopic pregnancies implant in the extrauterine portion of the Fallopian tube, and rupture occurs at around 5–7 weeks' gestation. However, an ectopic pregnancy in the intramural portion of the tube or in the cervix ruptures later, at 9–16 weeks.

Rupture of an ectopic pregnancy is usually an acute emergency. It should always be suspected in a woman of childbearing years who has collapsed with shock and lower abdominal pain. Classically, there is a history of a missed period and signs and symptoms of early pregnancy, but frequently these clues are absent, and even a previous sterilisation operation does not preclude the diagnosis. Haemodynamically unstable patients with this acute presentation require simultaneous resuscitation and surgical exploration. Thus, a general surgeon working in a hospital with no gynaecological service will be unable to transfer such a patient and will have to operate.

However, an ectopic pregnancy can be a subacute event. The signs and symptoms are largely related to whether the ectopic pregnancy is intact, has aborted into the peritoneal cavity or has ruptured through the tubal wall into the peritoneum or into the broad ligament. Pelvic peritoneal irritation may produce tenesmus and diarrhoea or mimic appendicitis. Intraperitoneal blood can irritate the diaphragm and produce shoulder tip pain. If the diagnosis of an ectopic has not been suspected preoperatively, a general surgeon may have made an incorrect alternative surgical diagnosis, proceeded to surgery and the ectopic pregnancy is only diagnosed at operation.

In women who are bleeding profusely, the first priority is to control the haemorrhage. After the peritoneal cavity has been entered, it may be difficult, because of the amount of blood in the pelvis and the continuing bleeding, to identify the affected tube. A hand inserted into the blood can feel the uterus, draw it up and then palpate the tubes to identify the affected side. Digital compression of the broad ligament, proximal and distal to the mass, will effect temporary control of haemorrhage until a clamp can be applied. Autotransfusion of the intraperitoneal blood is occasionally possible (see Appendix II).

SURGICAL OPTIONS

There are a number of surgical options to treat ruptured ectopic pregnancies, and debate continues regarding the merits of tubal linear salpingotomy, mid-tube resection with a later reanastomosis and fimbrial evacuation. However, unilateral simple salpingectomy has the merit of controlling the haemorrhage, excising the whole pregnancy and not leaving a damaged tube to give rise to a further ectopic. In the presence of a healthy contralateral tube there is no clear evidence that a salpingotomy should be used in preference to salpingectomy.[6] If the other tube is absent or severely damaged, and further children are wanted, a conservative operation, such as a salpingotomy, should always be considered.

Simple salpingectomy

The affected tube is clamped close to its uterine end. While the tube is held up by Babcock forceps, the mesosalpinx is divided close to the tube, between a series of clamps (**AA** in Figure 27.2). The tube is removed and the pedicles are tied off with absorbable transfixion sutures. The peritoneal cavity is cleared of blood and clot and if the pregnancy has already ruptured, a search should be made for the pregnancy sac to ensure its removal.

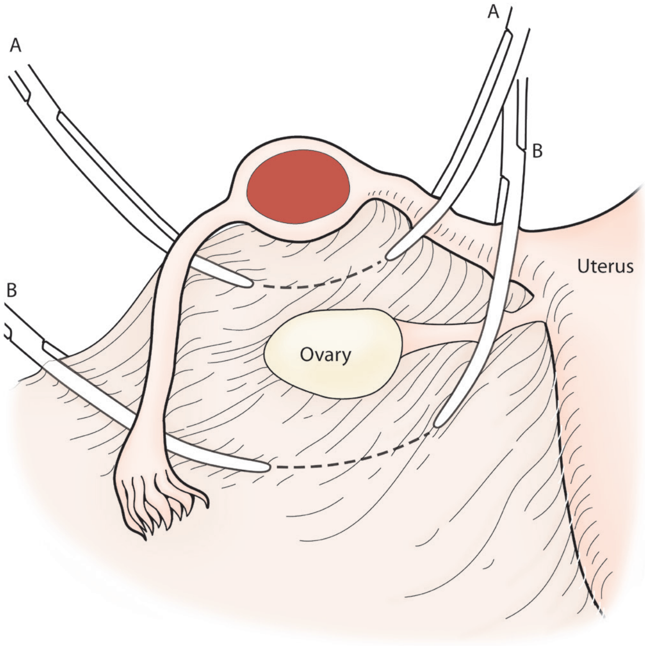

Figure 27.2 *Salpingectomy for ectopic pregnancy. Clamps are placed on the mesosalpinx and on the uterine end of the tube (AA). The infundibulopelvic ligament carrying the ovarian vessels is preserved. If the decision is made to remove the ovary along with the tube (a salpingo-oophorectomy), then the tissue between the clamps (BB) is removed.*

Fimbrial evacuation

If the tubal pregnancy is about to abort from the fimbrial end, then an attempt to complete the process by gentle pressure is permissible, but care should be taken to leave no trophoblastic tissue behind.

Linear salpingotomy

This incision allows complete removal of the pregnancy sac. Haemostasis is controlled with diathermy, and the incision in the tube does not require closure.

ATYPICAL ECTOPIC PREGNANCY

The two rarer forms of ectopic pregnancy described below present with atypical symptoms and signs.

Interstitial pregnancy

Ectopic gestation in the intramural portion of the Fallopian tube, although rare, can be the cause of rapid and profound haemorrhage. Cornual resection to remove the whole pregnancy is followed by a two-layer haemostatic repair of the uterus with deep interrupted sutures. Where haemorrhage cannot be controlled, a subtotal or total hysterectomy may be necessary.

Cervical ectopic pregnancy

In this rare event, the only treatment may be a total hysterectomy. Sometimes, however, it may be possible to save the uterus if haemorrhage can be controlled either by tamponade with a Foley catheter or by embolisation.

CONDITIONS AFFECTING THE OVARY

Ovarian cysts and tumours

Even with sophisticated preoperative imaging, the general surgeon will still occasionally operate, without a firm diagnosis, on a pelvic or abdominal mass and discover on entering the abdomen that the mass is ovarian. Similarly, a laparotomy for suspected peritonitis may reveal that the peritoneal irritation is from a complication of an ovarian cyst. Ovarian cysts are also not infrequently encountered by general surgeons as an incidental finding during the course of a laparotomy for some unrelated pathology. Gynaecological advice should be sought, but if this is not available, then the general surgeon will require some knowledge of the pathophysiology of ovarian cysts and solid tumours in order to respond appropriately.

- *Physiological cysts* include single or multiple follicular cysts, which contain straw-coloured fluid, and corpus luteal cysts, which are associated with haemorrhage of

varying degree either into the cyst or into the peritoneal cavity. Physiological cysts are seldom more than a few centimetres in diameter.
- *Endometriotic cysts* may be associated with other manifestations of endometriosis in the pelvis, and the ovary may be densely adherent to surrounding structures. Surface 'chocolate staining' is often absent as these cysts have a thick capsule. Incision reveals single or multiple tense dark cysts, which contain altered blood and, sometimes, blood pigment stones.
- *Serous cystomas* are unilateral, benign unilocular cysts with no glandular element; they can grow to contain several litres of clear fluid.
- *Dermoid cysts*, a form of ovarian teratoma, are semi-solid. They can be single or bilateral and may involve the whole or only part of an ovary. They contain sebaceous material and can also contain any tissue, including teeth. They are usually an incidental finding unless they have undergone torsion or rupture. When the latter happens, the leaked material is irritant and may induce a chemical peritonitis.
- *Solid benign tumours* are easily misdiagnosed as malignant by a general surgeon. Ascites can occur with a benign fibroma and, when combined with a right hydrothorax, it is known as Meig's syndrome, but it is comparatively rare.
- *Cystadenomas* are glandular cysts of the ovary and have a significant potential for malignant change. The serous cystadenoma contains straw-coloured fluid and the mucinous cystadenoma contains mucin. These cysts may be single or bilateral, unilocular or multilocular, and they may grow to a large size.
- *Cystadenocarcinomas*. Malignancy should be suspected if there are solid areas within the cyst or if there are surface papillomatous excrescences either on the serosal surface or on the cyst lining. General metastatic seeding on peritoneal surfaces, including the greater omentum, and the presence of ascites may make the diagnosis of malignancy more certain.

COMPLICATIONS OF OVARIAN CYSTS

Haemorrhage, rupture, torsion or infection can occur with any ovarian cyst and it is these complications that commonly bring the cyst to the attention of the surgeon. The complication is treated and the cyst is then managed on its merits.

- *Haemorrhage* may be into a cyst, with resultant tension and pain, or into the peritoneal cavity. Active bleeding from an otherwise harmless cyst may require diathermy coagulation or a haemostatic suture.
- *Rupture* of a cyst evokes a chemical peritonitis of varying severity, and the torn edges may bleed.
- *Torsion* of a normal ovary can occur, but it is more common when there is an ovarian mass. The torsion may be partial, with an engorged but viable ovary, or of several turns with complete vascular occlusion and rapid infarction. The Fallopian tube and ovary undergo torsion as a single unit and the pedicle thus formed can be simply clamped, divided and ligated if the ovary and tube are infarcted and require excision. In a partial torsion, untwisting may reveal a viable ovary that can be preserved.
- *Infection* is almost always secondary to another intraperitoneal infection. The cyst contents form an abscess, which must be drained.

SURGICAL OPTIONS

When a surgeon encounters a small physiological cyst in a premenopausal woman, no treatment is required. When an apparently benign cyst is of significant size (more than 5 cm in diameter) it is usually in the patient's interest that it should be removed. In considering the options, the surgeon should remember that only about 13 per cent of ovarian tumours that come to surgery before the menopause are malignant, in contrast to about 45 per cent after the menopause. Ovarian function should not be sacrificed in premenopausal women without good evidence of its necessity.

- An *ovarian cystectomy* preserves the ovarian tissue, even of the affected ovary. It is an appropriate operation for small, clinically benign cysts in a premenopausal ovary.
- A *unilateral oophorectomy* preserves the function of the contralateral ovary. It may be the more appropriate treatment of a larger benign cyst, where little functioning ovarian tissue remains, and is also the recommended treatment of a benign solid tumour of a premenopausal ovary. If, however, the contralateral ovary is absent or there is bilateral pathology, as is often the case in dermoid tumours, an ovarian cystectomy must always be considered.
- In the post-menopausal patient, a *bilateral oophorectomy* is usually recommended, even for an apparently benign cyst.

Occasionally, the surgeon strongly suspects that an ovarian tumour may be malignant. The standard surgical treatment of an ovarian primary cancer confined to the ovary is a total hysterectomy with a bilateral salpingo-oophorectomy and infracolic omentectomy. This wide excision gives the best chance of total surgical removal of any malignant spread and provides staging information that will influence subsequent treatment. However, the general surgeon will not be operating with a preoperative diagnosis of ovarian cancer and, although the ovary may appear malignant, there is no histological proof. There should be a reluctance to proceed with a major resection in the speciality field of another surgical discipline especially when, if the histology is finally reported as benign, such a major operation will be found to have been unnecessary. Additionally, the patient may feel that adequate preoperative discussion was not undertaken. For all of these reasons, a unilateral salpingo-oophorectomy is probably the best strategy for the general surgeon faced with this situation. When there is still no contamination of the peritoneal surface from tumour excrescences on the serosal surface, complete removal without spillage is extremely important. If malignancy is confirmed and further surgery indicated, it can be completed at a second procedure.

More frequently in ovarian cancer, the tumour is found to have already disseminated intraperitoneally at the time of laparotomy. A total hysterectomy, bilateral salpingo-oophorectomy and infracolic omentectomy are indicated as a debulking procedure, as chemotherapy is more effective on small-volume disease. Ovarian cancer is more responsive to chemotherapy than most gastrointestinal malignancies, and a long remission can be achieved even in advanced disease. However, general surgeons who find themselves unexpectedly in such an abdomen, without gynaecological advice, may find it best simply to take a generous biopsy of the involved omentum for histological confirmation. If ovarian cancer is confirmed, the patient can then be transferred to a gynae-oncology centre for optimal further management.

In very advanced disease, the initial laparotomy has often been performed by a general surgeon, as the patient has presented with abdominal distension and an intestinal obstruction, the aetiology of which is obscure until the abdomen is opened. Disseminated malignancy and malignant adhesions are encountered and the primary lesion is thought probably to be ovarian. Small bowel obstructions can be bypassed, but a large bowel obstruction in the pelvis most often necessitates a proximal loop colostomy. If an omental biopsy confirms disseminated ovarian malignancy, chemotherapy will usually offer palliation.

The surgeon must remember that malignant ovarian tumours may also be secondary deposits, which are often larger and more apparent than the primary tumour, and they may occur either with or without other evidence of intraperitoneal seeding. *Pseudomyxoma peritonei syndrome* and *disseminated mucus-producing gastrointestinal adenocarcinoma* can produce a clinical picture identical to that of a disseminated ovarian primary. In either pathology there may be extensive intraperitoneal disease or the pathology may appear initially to be confined to an ovary. If pseudomyxoma peritonei is confirmed histologically, the patient should be referred to a specialist centre; subsequent surgery in the pelvis will be more hazardous if an initial hysterectomy has been performed (see Chapter 16). Secondary tumours in the ovaries from gastrointestinal or breast malignancy may be large and cause symptoms. There may be no other macroscopic metastatic spread and a bilateral oophorectomy may give very worthwhile palliation. This is also discussed further in Chapter 16.

OVARIAN SURGERY

Surgery on the ovary is generally straightforward unless an ovary is found densely adherent to adjacent structures or is lying retroperitoneally.

Ovarian cystectomy

An incision is made through the ovarian cortex around the base of the cyst, deep enough to expose a plane of cleavage, which is developed by sharp or blunt dissection so that the cyst can be enucleated (Figure 27.3). After haemostasis, the ovary can be closed with an absorbable suture, taking care to abolish any dead space, which may fill with blood.

Oophorectomy

Oophorectomy requires the division between clamps and subsequent ligation of the infundibular pelvic ligament to secure the ovarian vessels. Separate ligation of the ovarian ligament may also be necessary (Figure 27.4).

Salpingo-oophorectomy

Salpingo-oophorectomy is often the better option in a large cyst with the Fallopian tube stretched over its surface (Figure 27.5). A large serous cystoma can be drained down to a more manageable size before removal. A needle, attached to low-pressure suction, is passed through a purse-string suture placed in the cyst wall. It is important to isolate the area with packs and to minimise any spillage during aspiration. The needle is then withdrawn, the defect closed with the

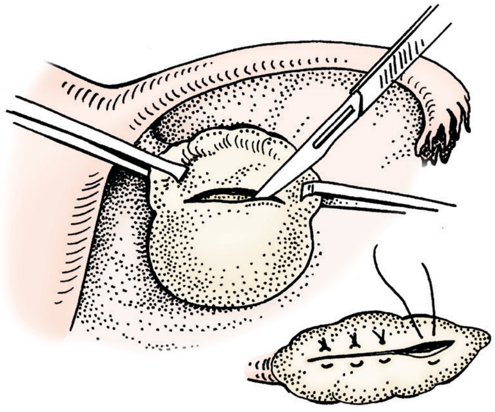

Figure 27.3 *Ovarian cystectomy. The cyst is shelled out through an incision around the base of the cyst. A sutured repair of the ovary is shown in the inset.*

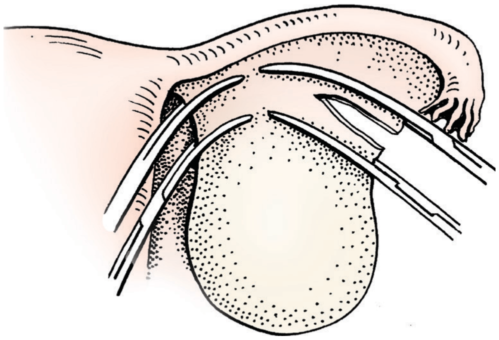

Figure 27.4 *Oophorectomy. The indundibulopelvic fold and the ovarian ligament are divided between clamps.*

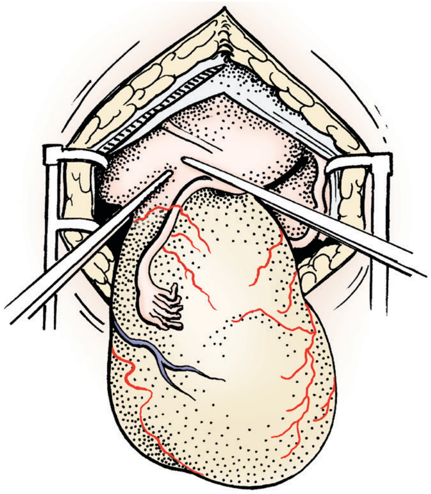

Figure 27.5 *Salpingo-oophorectomy. The lateral pedicle clamp is on the infundibulopelvic fold containing the ovarian vessels. On the uterine side the clamp is across the ovarian ligament and the proximal Fallopian tube.*

purse-string suture and removal of the cyst or ovary completed. This manoeuvre will enable the surgeon to remove the cyst through a smaller abdominal incision. However, the surgeon must remember that a large cyst, especially in a postmenopausal woman, may ultimately prove to be malignant. If malignancy is a possibility, aspiration is contraindicated as it is vitally important that there is no contamination of the peritoneal cavity with malignant cells. Instead, the abdominal wound must be enlarged to allow adequate access for gentle delivery of the cyst and identification of its pedicle.

The lateral part of the pedicle is formed by the infundibulopelvic ligament containing the ovarian vessels which, in the case of a large cyst, are likely to be much dilated. The medial or uterine part of the pedicle contains the Fallopian tube and the ovarian ligament. Separate clamps are placed on the two parts of the pedicle. Care must be taken to avoid inclusion of the ureter in the clamps on the lateral pedicle. It is advised that two proximal clamps and a transfixion ligature should be employed on the lateral pedicle because if a clamp or ligature slips, the cut ovarian vessels may retract behind the peritoneum. Haemorrhage may be profuse and the cut ends difficult to identify.

Excision of retroperitoneal ovarian cysts

Excision of retroperitoneal ovarian cysts may be challenging. They tend to form when the cyst develops in the presence of surface adhesions and are not uncommon after a previous hysterectomy. These cysts are rarely malignant and seldom contain glandular tissue. The best approach is to open the peritoneum over the surface of the cyst, between the round ligament and the Fallopian tube, which are usually both stretched over it. A plane of cleavage is sought and developed digitally. The vascular pedicles should not be clamped until the ureter has been identified, as it lies in close proximity to the posterior surface of the cyst.

CONDITIONS AFFECTING THE UTERUS

General surgical practice is less commonly affected by uterine pathology than tubo-ovarian pathology. However, an enlarged fibroid uterus may obscure surgical access to the pelvis and an advanced tumour of the uterine body or cervix may invade the bowel.

Endometriosis

This gynaecological condition of ectopic endometrial tissue may have an impact on general surgical practice. The most common variety is of pelvic peritoneal nodules, which cause pelvic pain, and a laparotomy may have been performed by a general surgeon for some other suspected pathology. Early lesions are dark brown or purplish nodules a few millimetres in diameter, but later puckering and scarring of the peritoneum are more prevalent. Dense adhesions may form around the Fallopian tubes, and in severe cases adhesions obliterate the rectovaginal pouch, involving the anterior rectal wall in the scar tissue. When encountered unexpectedly by the general surgeon, no surgical action is required. The overall management of endometriosis is complex, and any surgery that is indicated is supported by hormone manipulation.

Rarer forms of the disease are often only diagnosed after excision. A small bowel loop may be strictured by the scarring from a nodule of endometriosis on its wall. A sigmoid or rectal wall lesion may present with a stricture or with ulceration into the lumen and haemorrhage. A tender lump within a caesarean section scar, explored as a possible incisional hernia, will sometimes prove to be ectopic endometrial tissue.

Hysterectomy

The general surgeon may have to remove the uterus *en bloc* with a rectal or sigmoid colon cancer that is invading the cervix or body of the uterus, and the hysterectomy is combined with a radical colonic or rectal resection. A similar challenge is posed by a locally advanced gynaecological cancer invading the rectum. These operations should ideally be performed as a combined procedure involving both specialists, but a colorectal surgeon will find that the additional dissection necessary for the hysterectomy is often relatively minor in this situation. In addition, the standard steps described in a hysterectomy must be modified so that the dissection does not breach the area of tumour invasion between the two organs. Occasionally, although the hysterectomy is not required for oncological reasons, pelvic access is restricted by a bulky fibroid uterus, and a hysterectomy has to be performed to allow a safe rectal dissection. Rarely, a general surgeon working in a hospital without gynaecological colleagues may have to perform an emergency hysterectomy for obstetric haemorrhage.

Total and subtotal hysterectomy are described, but vaginal hysterectomy and the extended Wertheim hysterectomy for carcinoma of the cervix are outwith the scope of a general surgical operative text. In a total hysterectomy, the whole of the uterus, including the cervix, is removed. A subtotal hysterectomy removes the body of the uterus, but leaves the cervix. Carcinoma of the cervical stump is uncommon, but the patient should be advised to continue with cervical smears if they are available. The subtotal operation is quicker and easier to perform, with a faster recovery and lower mortality and morbidity. It should always be considered in benign disease when there is poor access to the cervix due to obesity, fibroids or adhesions, or when the patient's condition precludes a more prolonged procedure.

In both a total and a subtotal hysterectomy, conservation of the ovaries is preferable in the premenopausal woman, if at all possible. However, a bilateral oophorectomy should be offered when planning a hysterectomy in the postmenopausal woman, as the additional morbidity is minimal and ovarian removal almost completely prevents the development of a subsequent ovarian malignancy.

TOTAL HYSTERECTOMY

In situations where a general surgeon is involved, the abdomen will normally already have been opened through a midline incision. A Pfannenstiel incision, however, also provides good access for a hysterectomy. All pelvic surgery is easier with the patient tipped head-down and the small bowel held out of the pelvis with packs. A general surgeon will probably choose first to identify the ureters in familiar territory above the pelvic brim and to follow them distally before embarking on any pelvic dissection.

The uterus is elevated and a clamp, such as a Jessop, Oschner or Kocher, is placed across each cornu, incorporating the round ligament, the ovarian ligament and the Fallopian tube. The tip of each clamp is angled laterally into an avascular 'window' in the broad ligament. Further clamps are applied alongside and parallel to the first, and the tissue divided between them. The pedicles are transfixed and ligated. The original cornual clamps remain in place and are used to retract the uterus. If the ovaries and tubes are to be removed, the round ligament is clamped lateral to where it separates from the Fallopian tube, and the infundibulopelvic ligament containing the ovarian vessels must also be secured as already described in the section on salpingo-oophorectomy.

Digital development of the space between the leaves of the broad ligament can be helpful at this stage. The peritoneal incision in the anterior leaf of the broad ligament is then carried downwards close to the uterus towards the base of the ligament, and is then continued towards the midline across the uterovesical pouch at the junction between uterus and cervix where the peritoneum is loose (Figure 27.6a). The anterior flap of peritoneum is raised to expose the bladder. The fascial strands between the cervix and bladder are divided to open a plane of cleavage. The bladder, with the lower half of the vesicouterine fold of peritoneum, is now pushed down off the cervix and the upper part of the vagina. This carries the ureter downwards with the bladder to below the level of the uterine artery, and should safeguard it when the vessel is clamped. More laterally, stripping must be done gently as parametrial venous plexuses may be torn. When the cervix is long or there is scarring from a previous caesarean section, it may be necessary to leave the final dissection of the bladder off the cervix and vaginal vault until the uterine vessel pedicles have been divided.

The uterine vascular pedicle is secured with a clamp, angled at almost 90 degrees to the cervix, with the tip on the cervix itself so that when the clamp is closed the tip slips off

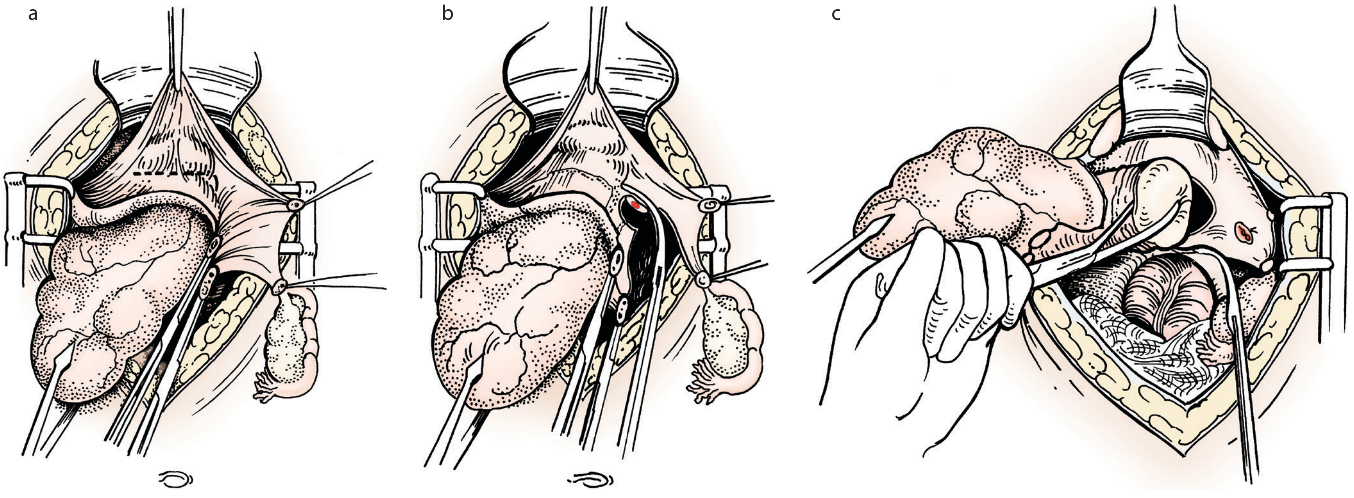

Figure 27.6 *Hysterectomy. (a) The right Fallopian tube and round ligament have been clamped separately in this illustration. The laterally placed clamps have been tied off and the medial clamps retained as retractors. The uterovesical peritoneal fold has been elevated and the planned incision is shown. (b) The bladder has been displaced downwards off the cervix. The uterine vessels are then clamped close to the uterine wall. (c) The vagina is opened and a vulsellum retractor placed on the cervix for retraction while the vaginal division is completed.*

to grip tissue as close to the cervix as possible. A second clamp is applied, parallel to the first, the uterine vessels are divided and then transfixed and ligated (Figure 27.6b).

Any further dissection to expose the vagina is completed and the vagina is opened transversely, with scalpel or diathermy, in the midline anteriorly until a vulsellum retractor can be placed on the anterior lip of the cervix (Figure 27.6c). Combined upward traction on the vulsellum and the cornual clamps places the lateral vaginal angle on tension. An angled Kocher clamp is applied to incorporate the lateral vaginal angle, the descending cervical branch of the uterine artery and the uterosacral ligament posteriorly. The uterosacral ligament may need to be taken separately if it is thickened because of endometriosis or chronic inflammation. Releasing the uterosacral ligaments usually results in the uterus becoming more mobile and may aid the surgery. The circumferential vaginal incision is completed posteriorly and the uterus removed.

In situations where there is a malignancy invading across the rectovaginal pouch, the posterior incision through the vaginal wall must be well below any tumour invasion, and access will have to be from the sides. The excised tumour specimen may then include a major portion of the posterior vaginal wall.

Each vaginal angle is undersewn by an over-and-over suture, starting at the tip of the clamp and working laterally. It incorporates the vagina at front and back, with the last pass being under the heel of the clamp. The clamp is removed and the suture drawn tight and tied. The vagina is then closed with a continuous haemostatic suture (no. 1 Dexon™ is suitable). If there is concern over haemostasis, the vaginal edge should be oversewn to leave a central aperture through which a wide **T**-tube drain can be placed. There is no need to close the pelvic peritoneum.

SUBTOTAL HYSTERECTOMY

The operation is performed as for a total hysterectomy up to, and including, ligation of the uterine vascular pedicles. The dissection is not then carried so deeply into the pelvis and the bladder is not separated from the vaginal vault. The cervix is divided through its extravaginal portion and oversewn with absorbable sutures. This closure can be improved if the two halves of the cervix are cut into a **V**-shaped wedge.

POST-PARTUM HYSTERECTOMY

Very occasionally, a general surgeon may be required to carry out this operation for uncontrollable haemorrhage. Generally, the tissue planes are well developed and the enlarged blood vessels easy to identify. However, identifying the limits of the dilated cervix may be difficult and can lead to incomplete removal. The surgeon unfamiliar with total abdominal hysterectomy would be wise to consider the subtotal operation. A hysterectomy must occasionally be combined with a caesarean section. Closure of the uterine caesarean incision before embarking on the hysterectomy is recommended to reduce haemorrhage.

SURGERY IN PREGNANCY

Any surgical pathology may present in pregnancy. Surgery in the first trimester is complicated by concerns regarding the possible teratogenic effects of anaesthetic drugs and any abortifacient effect of the condition requiring surgery or of the surgery itself. Elective surgery should therefore be avoided during this period. However, as intraperitoneal sepsis is a more powerful factor than intra-abdominal surgery in inducing a miscarriage, the surgeon should not err on the side of conservative management when, for example, appendicitis is suspected. The initial concern over the dangers of laparoscopy in pregnancy appears to be unfounded.

In mid-trimester the chances of miscarriage are low, the risk of major teratogenic effects has passed and the uterus is not yet obscuring access. This is therefore the optimum period to operate if postponement of surgery until after delivery appears unwise. Diagnosis of abdominal conditions in late pregnancy can be difficult, as the uterus is in contact with most of the anterior abdominal wall, masking physical signs from gastrointestinal pathology, and all the abdominal organs are displaced cranially from their normal anatomical sites. Access for surgery is difficult and in addition, the patient lying supine will often obstruct her venous return by the weight of the gravid uterus on the inferior vena cava. The surgeon will thus have to operate with the patient tilted, usually into a partial left lateral position. Close to term, a laparotomy for surgical pathology may sometimes be best combined with a caesarean delivery.

Avoidance of radiation to the fetus is important throughout pregnancy, and surgery may be hampered by the lack of preoperative or intraoperative imaging. Ultrasound and MRI can be safely used in pregnancy.

The life-threatening emergencies associated with pregnancy itself, and which require urgent surgical intervention, will only involve a general surgeon if no gynaecologist is available. Ectopic pregnancy was discussed earlier in this chapter (p. 505).

Emergency caesarean section

Operative intervention to deliver a baby may be necessary either in late pregnancy or in labour. There may be extreme urgency when severe fetal distress indicates that the life of the baby is threatened from whatever cause. There is also urgency to deliver, even a stillbirth, when the life of the mother is threatened by eclampsia or by haemorrhage. Neither eclampsia nor haemorrhage can be controlled until the uterus is emptied. These are probably the only situations in which a general surgeon may unexpectedly have to act as an obstetrician in an emergency. Intervention with less urgency may be required during a labour that fails to progress whether for mechanical or for physiological reasons.

In the emergency situation, a caesarean section is necessary if imminent vaginal delivery cannot be achieved. Assisted vaginal delivery by forceps or vacuum extraction is often preferable if the head is engaged in the pelvis and the cervix is fully dilated. A symphysiotomy (see below) should be considered, and a vaginal delivery of a dead fetus after cranioclast collapse of the cranium may also be a safer alternative to a caesarean section in some circumstances.

Today, an emergency caesarean section virtually always utilises a lower segment incision rather than the classical procedure. In a classical caesarean section the upper segment of the uterus is opened through a vertical incision and the fetus is delivered as a breech. In the lower segment operation, the lower uterine segment is incised transversely and the fetus is delivered head first if the vertex is presenting. A lower midline incision in the abdominal wall can be used for both, but the transverse Pfannenstiel approach is favoured for most lower segment operations and only takes marginally longer to perform.

LOWER SEGMENT CAESAREAN SECTION

A lower segment caesarean section can be performed under general, spinal, epidural or even local infiltrative anaesthesia. A general anaesthetic in labour, without adequate airway protection, carries a high risk of inhalation of gastric contents. In addition, anaesthetic drugs will cross the placenta and may depress the baby's respiratory efforts after delivery. Regional anaesthesia may therefore be safer if anaesthetic skills are limited. The mother should be catheterised and placed with a 10–15-degree left lateral tilt to prevent pressure of the uterus on the vena cava.

Operative procedure

Whichever incision is chosen, it must be long enough to accommodate the fetal head with a hand alongside. Care must be taken on opening the peritoneum to avoid injury to the bladder. The uterus is then checked for rotation, which is virtually always to the right. If wet packs are used to isolate the uterus from the rest of the peritoneal cavity, a pack placed first on the right side may help to correct this rotation.

The lower segment is identified as that area beneath the vesicouterine reflection of peritoneum where the peritoneum lies free of the uterine wall. This fold of peritoneum is picked up and incised transversely almost as far as the broad ligament. The lower half, with the bladder attached, is then pushed down to expose the lower segment. There may be dilated veins overlying the lower segment. These can be oversewn or merely kept compressed by an assistant while the lower segment is opened. A Doyen, or similar retractor, is used to hold the bladder and peritoneum down and out of the way.

A 3–4-cm transverse incision is made in the uterine muscle, high in the lower segment, and deepened until the membranes bulge, which they will do if amniotic fluid is still present in quantity. It does not matter if the membranes are opened at the initial incision, but there is greater control if this is done as a separate layer. Too low an incision in the lower segment must be avoided, as it may not be possible to create a long enough incision in this narrower portion to deliver the fetus, and tearing can occur either down into the cervix or laterally into the uterine vessels or ureter. The lower uterine segment may be very thin after a prolonged labour, and care must be taken not to cut too deep and lacerate the fetus.

The incision is then extended laterally, and a finger can be inserted to protect the fetus. Before labour is established, and particularly in a pre-term pregnancy, the lower segment is poorly developed and there is a danger of entering the uterine arteries as the incision is carried laterally. A 'smile'-shaped incision with the lateral extensions curved upwards may overcome this problem and is a better solution than the classical incision. It is wise to place a stay suture at the midpoint of the lower edge of the uterine incision so that it can be found more easily when closing the uterus.

The presenting part must now be delivered up from the pelvis. In a cephalic presentation the surgeon slides the fingers of one hand down alongside the head to release the vacuum of a tight fit; there is more room over the face. The hand is then used as a 'scoop', or one forceps blade as a 'shoehorn', to draw the head up to the lower segment opening. Fundal pressure then assists delivery. The head should be allowed to deliver slowly and flexion should be maintained to reduce the diameter of the fetal head as it is drawn through the uterine incision.

A deeply impacted head may be difficult to deliver up, and an assistant pushing it up from the vagina is helpful. A high, free-floating head can also pose difficulty and is easiest solved by finding the anterior ankle, doing a podalic version and delivering the baby by breech extraction.

The baby is delivered and its airway is attended to by an assistant while the surgeon completes the operation. The umbilical cord is ligated, or clamped, and divided. Ergometrine is given to speed the natural contraction of the empty uterus and the separation of the placenta. Normal physiological separation of the placenta should then be awaited but, if delay occurs, gentle cord traction can be applied if the fundus is contracted. Meanwhile, brisk bleeding from the edges of the uterine incision can be controlled with non-crushing Green–Armitage or Rampley clamps.

The placenta and membranes should be checked for completeness and the uterine cavity is checked digitally. If a closed internal os is felt, it should be gently stretched with a finger to allow free drainage of lochia.

The uterine incision is then closed. A continuous haemostatic suture is satisfactory and should be started from both ends, as haemorrhage is not only most profuse from the lateral angles, but access is most difficult. These initial lateral angle sutures can be placed before delivery of the placenta and will reduce blood loss. A heavy, long-acting absorbable material, such as 0 or 1 Dexon™, is suitable for uterine closure. A two-layer closure is recommended unless the lower segment is very thin. Beware of including the bladder in the stitch or of sewing the upper edge of the uterine incision to the posterior wall of the uterus. Any isolated bleeding points can be controlled by an additional interrupted suture. It used to be traditional to close the vesicouterine fold of peritoneum as a loose third layer, but this is now often omitted. The peritoneal cavity is cleared of liquor and blood, and the abdomen closed.

CLASSICAL CAESAREAN SECTION

The classical vertical incision through the uterine body leaves a scar that is more liable to rupture in future pregnancies, and should be avoided if possible. Indications for a classical incision may be absolute or relative, but include a mother who is dead though her baby is still alive, a gross fetal abnormality, a cervical cancer, an anterior placenta praevia and a very premature pregnancy with a poorly defined lower segment.

The preparation of the patient is similar, the abdomen is opened through a lower midline incision and a midline vertical incision of at least 15 cm is made in the body of the uterus. A cephalic presentation is then delivered as a breech extraction. The management of the third stage and the uterine closure are similar to those described for a lower segment caesarean section.

Symphysiotomy

A symphysiotomy is a deliberate surgical separation, either full or partial, of the symphysis pubis in order to enlarge the capacity of the pelvis and allow the passage of a living child. It is a safer procedure in unskilled hands than a caesarean section in difficult circumstances, but the potential for long-term skeletal and urinary morbidity has made it an historic procedure in the developed world. However, a symphysiotomy avoids a uterine scar and the symphysis can separate again in a subsequent labour. This is a safer scenario for a woman who is living far from medical facilities, who has a mildly contracted pelvis and who will probably have multiple further pregnancies.

The ligaments of the pubic symphysis are softened by pregnancy and divide easily with a scalpel. A firm urethral catheter is inserted. A finger within the vagina can then hold the urethra safely to one side during the release. Local anaesthetic is infiltrated down to the periosteum. A large scalpel, with its cutting edge facing the perineum, is passed through the skin overlying the junction of the upper and middle thirds of the symphysis pubis, and is advanced through the symphysis until the tip can just be felt by the vaginal finger. The distal two-thirds of the symphysis is then divided with a sawing movement. If the superior ligament can be left intact, post-delivery morbidity will be reduced, but if necessary this can also be divided. A large episiotomy is performed, but a forceps or vacuum extraction may still be necessary. The symphysis should open by 2–3 cm, but excessive diastasis must be prevented, especially as the head is crowned. It is important after the symphysiotomy has been performed that the patient's legs are not fixed in supports in the lithotomy position, and that two assistants are delegated to support the legs, restricting the degree of abduction and giving lateral support to the pelvis. In this way the degree of separation of the divided joint can be controlled.

The pubic symphysis heals spontaneously and no fixation is required. Urinary catheterisation should be continued for several days and early mobilisation encouraged with adequate analgesia.

Severe haemorrhage in the obstetric patient

In all situations, maternal blood loss will continue unabated until the baby and the placenta have been delivered and the uterus can contract and close the open sinusoids. Retained products of conception, or even blood clot, can also prevent satisfactory uterine contraction.

PRE- AND INTRAPARTUM HAEMORRHAGE

If the fetus is still *in utero*, it must be delivered immediately and this will usually require a caesarean section. A retained placenta is also associated with haemorrhage, and the first priority, alongside resuscitation, is delivery of the placenta. A general surgeon is unlikely to be involved until after the standard manoeuvres of oxytocin administration, fundal rubbing and controlled cord traction have failed. Manual removal of the placenta is the next step, and if this fails, due to a morbidly adherent placenta that intrudes through the uterine wall, an emergency hysterectomy may be required to control haemorrhage. Uterine inversion, sometimes associated with a placenta that is still attached, presents with haemorrhage, profound shock out of proportion to the blood loss and a mass in or outside the vagina. The uterus should be returned to its normal position as soon as possible, before the cervix contracts necessitating a general anaesthetic for replacement. Reduction is achieved by manual manipulation within the vagina, and any attempt to remove a retained placenta is delayed until the uterus has been restored to its normal position. After reduction, and additional manual removal of the placenta if it is still attached, the surgeon's hand should remain inside the uterine cavity, to prevent recurrence of the inversion, until the uterus starts to contract. A uterine inversion can also be reduced by hydrostatic pressure. Saline (2 litres) is run into the posterior fornix from a height of 2 metres, and both hands are used to hold the vagina closed and prevent fluid escape.

POST-PARTUM HAEMORRHAGE

Resuscitation should run parallel with the assessment of the cause of haemorrhage. The abdomen is palpated and if the uterus is found to be well contracted, the likely source is genital tract haemorrhage from trauma to the perineum, vagina or cervix. This should be explored and repaired. A *cervical laceration* can cause massive haemorrhage immediately after delivery, and can usually be sutured *per vaginam*.

If the uterus is not contracted, the standard obstetric manoeuvres of oxytocin and prostaglandin administration, fundal rubbing and even manual exploration of the uterine cavity to remove clot and retained membranes will almost always have been undertaken before a general surgeon is involved. Packing of the uterine cavity may have been tried, but is seldom helpful. Tamponade with a Bakri balloon, or alternatives such as a Sengstaken–Blakemore tube inflated up to 300 ml or a Rüsch balloon, may be a better temporary solution. In the absence of any of these devices, a surgical glove or condom tied with suture material to a plastic catheter may have the same effect. (A Foley catheter balloon can be used for a similar haemorrhage in early pregnancy.) The patient can then be fully resuscitated and clotting restored to normal. With haemorrhage continuing from an atonic empty uterus, the choices are embolisation, a brace suture to compress the uterus, uterine or internal artery ligation or a hysterectomy.

B-Lynch brace suture

This ingenious compression suture, first described in 1997, is now a recognised technique[3,7]. The patient is anaesthetised in a semi-lithotomy position so that the rate of bleeding per vaginum can be monitored. The abdomen is opened and the uterus lifted out of the abdominal cavity and manually compressed. If this manoeuvre successfully stems the haemorrhage, the suture is worth trying. The vesicouterine peritoneal fold is divided as for a caesarean section and the lower segment exposed. A heavy absorbable suture (originally described with No. 2 chromic catgut) on a large round-bodied needle is required. The needle is passed from below upwards, entering the right side of the uterus 3 cm below the limit of the lower segment and 3 cm from the lateral border. The suture is brought out 3 cm above the limit of the lower segment and 4 cm from the lateral border. The stitch is then taken up and over the compressed fundus, 3–4 cm from the right cornual border. The suture is then carried down and enters the posterior wall of the uterus opposite and at the same level as the upper entry point at the front, and is carried through and around to emerge at the same level on the left posterior surface. It is then carried up the back and over the fundus 3–4 cm from the left cornual border, down the front of the uterus to enter 3 cm above the lower segment and emerges 3 cm below at the same distance as on the right side (Figure 27.7a). The two ends are then pulled tight, an assistant compressing the uterus bimanually, and tied (Figure 27.7b). The original report recommends that the lower segment is opened. However, surgeons using this technique have not always found this step necessary for success. If the lower segment has been opened, it is then closed in a similar manner to that after a lower segment caesarean section.

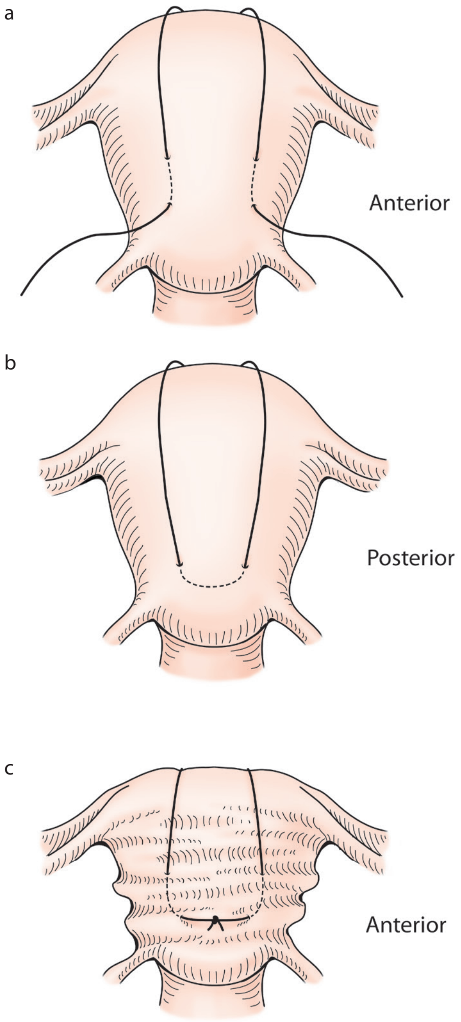

Figure 27.7 *B-Lynch brace suture. (a) The position of the suture viewed from in front and behind before it is tightened. (b) The suture is tightened, compressing the uterus and its arterial inflow.*

Internal iliac artery ligation

About 50 per cent of emergency hysterectomies for haemorrhage can be prevented by using this technique. However, it is not an easy operation and the surgeon must remember that the first priority is to save the life of the woman, and this must not be further jeopardised by futile attempts to save her uterus. A uterine rupture or cervical laceration that extends out into a uterine vessel can cause major haemorrhage, which cannot be controlled as the torn ends of the uterine vessel cannot be safely secured. Blind sutures risk injury to the ureter. Ligation of the internal iliac artery, or its posterior division, on the side of the haemorrhage is occasionally effective. However, there is an extensive collateral blood supply to the pregnant uterus and even bilateral internal iliac artery ligation may not stem a post-partum haemorrhage, whether from an atonic uterus or from obstetric trauma. This is a similar situation to that encountered in major pelvic fractures, where the haemorrhage is more satisfactorily controlled by embolisation (see Chapter 5, p. 70). Unfortunately, in situations where a general surgeon is involved, in the absence of a gynaecological colleague, there are often no interventional radiological skills available either.

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APPENDIX I: PREOPERATIVE PREPARATION

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Preoperative and postoperative care are vitally important and, in general, are the responsibility of the surgeon. The preoperative period should be used for relevant investigations and for preparation for surgery. This preparation may relate to the surgery itself – for example, control of thyrotoxicosis before thyroidectomy – but may also include optimisation of the patient's general condition and the management of coexistent medical pathology.

The risks of surgery and general anaesthesia are increased in the patient who has poor perfusion and oxygen delivery to vital tissue. Many patients requiring emergency surgery are in this compromised state. The underlying pathology may be hypovolaemia, cardiac failure, anaemia, sepsis or respiratory failure. Adequate delivery of nutrients to tissue is also important, as is the ability to eliminate metabolites. Hepatic or renal impairment will jeopardise these essential functions. Any hepatic or renal impairment will be compounded by poor oxygen delivery to the liver or kidneys. Sepsis is increased if the gut is underperfused. Thus, improvement in oxygen delivery to the tissues would appear to be the most important general resuscitative goal in the ill patient prior to emergency surgery. In some studies a focused approach to improved oxygen delivery has improved outcome,[1] but trial results have not been consistent. In elective surgery, preoperative treatment of concomitant cardiorespiratory pathology and improvement in nutritional status can also be achieved.

AVAILABLE TIME FOR PREOPERATIVE OPTIMISATION

The time available for general preoperative preparation of a patient is highly variable and dependent on the rate of deterioration in the underlying surgical condition. The surgeon may have from a few minutes to many months in which to make improvements.

The 4-minute window

This is the situation when the patient's only chance of survival is with immediate surgery. Examples include exsanguinating haemorrhage and cardiothoracic trauma where the mechanics of gas exchange and cardiac output have been disrupted. Surgery has to proceed alongside general resuscitation and forms an integral part of it. This salvage surgery is discussed further in Chapters 1, 6, 7, 8 and 15.

The 4-hour window

Many gastrointestinal surgical emergencies are included in this category. Patients are often fluid and electrolyte depleted and although preoperative resuscitation is important, the underlying pathology is advancing. The timing of surgery is important and full use must be made of this preoperative window in the light of haematological and biochemical values, emergency imaging and ECG findings (see Chapters 12 and 15).

Fluid and electrolyte replacement

The initial loss of fluid and electrolytes is from the intravascular compartment. Equilibration occurs rapidly within the whole extracellular compartment, and interstitial fluid is drawn into the circulation. Equilibration between the intracellular and extracellular fluid compartments follows. A standard 70-kg man has a total body water content of 40 litres (60 per cent of the total body weight). Fluid and electrolyte loss that has occurred over several days will therefore have depleted all fluid compartments, and the total deficit may exceed 10 litres. There is frequently relative sparing of intracellular fluid. Fluid replaced into the intravascular compartment must again equilibrate with other compartments, and a too rapid replacement will merely overload the circulation with deterioration in perfusion and oxygen delivery. Central venous pressure measurement (typically 3–8 mmHg) and urine output (over 30–50 ml per hour) are good guides during rehydration unless there is also renal impairment or cardiac failure, when more intensive monitoring may be required.

The sodium and potassium content of gastrointestinal secretions is shown in Table 12.1 (p. 201). Fluid lost from burns has a similar high sodium content. Normal saline is therefore the basic fluid for replacement of abnormal fluid losses. A fall in serum potassium is a late indicator of depletion of total body potassium, which is mainly in the intracellular fluid. Therefore, if potassium is known to have been lost, it should be replaced even if the serum potassium is not below normal. Solutions of 5 per cent dextrose have no place in the replacement of abnormal losses and can only compensate for reduced oral fluid intake.

Cardiorespiratory impairment

Improvements in cardiac output, perfusion and systolic blood pressure should occur as dehydration and hypovolaemic shock are treated. An inefficient cardiac rhythm, such as fast atrial fibrillation, can be controlled by intravenous beta blockade or digoxin. Congestive cardiac failure may be improved with a fast-acting diuretic or vasodilator. Bronchodilators or steroids may improve bronchospasm. A decision may be taken preoperatively that a patient will require postoperative admission to an intensive care unit for a period of planned artificial ventilation and inotropic cardiac support.

Intensive preoperative maximisation of oxygen delivery. This requires intensive care monitoring, including measurements of cardiac output and arterial oxygen saturation. An oxygen delivery of 600 ml/minute/m^2 is sought. Fluid replacement, increased inspired oxygen concentrations and inotropes may be needed to achieve this level.

Correction of abnormalities of clotting

The patient is usually aware of any inherited coagulation abnormalities. Acquired coagulation defects are more common, particularly in the context of an acutely ill patient. A drug history is also important; aspirin and clopidogrel induce a defect in platelet function, associated with a prolonged bleeding time and 'oozing' at operation. Many other drugs, including non-steroidal anti-inflammatories, direct anti-thrombins and some antidepressants, such as citalopram, are also associated with an increased risk of bleeding. Measurement of full blood count and a coagulation screen help in the initial assessment when a clotting abnormality is suspected. A low platelet count ($<50 \times 10^9$/l) should be corrected with a platelet transfusion. A prolonged prothrombin time (PT) and activated partial thromboplastin time (APPT) due to vitamin K deficiency or liver impairment can be corrected by using fresh-frozen plasma or, where appropriate, prothrombin complex concentrates.[2] Patients on warfarin should receive vitamin K in addition to fresh-frozen plasma. Heparin anticoagulation can be stopped and reversed, if necessary, with protamine, although low-molecular-weight heparin may only be partially reversed.

Endocrine abnormalities

Diabetic patients may be extremely unstable in an emergency situation. Commonly, they are ketoacidotic, but diabetic control will not be fully possible until the necrotic tissue or septic focus has been treated surgically. Surgery has to proceed alongside management of the patient's ketoacidosis. The occasional patient will be hypoglycaemic from a long-acting oral agent or insulin and a cessation of oral intake. Any patient on oral *steroids* requires parenteral steroid administration at increased dosages (see below).

The 4-day window

A delay of several days allows more formal preparation for surgery. A laparotomy for a non-strangulating bowel obstruction, surgery for obstructive jaundice or an amputation for irreversible ischaemia of a limb may all fall into this category. Medical treatment can be instituted for cardiac failure or hypertension. Preoperative treatment of obstructive airway disease or a respiratory infection, with physiotherapy, bronchodilators and antibiotics, may all be beneficial. Anaemia can be corrected with blood transfusion preoperatively. Perioperative diabetic management can be planned and diabetic patients on oral agents are usually temporarily converted to insulin. Jaundiced patients are at increased risk of postoperative renal failure. This is now believed to be mainly secondary to fluid shifts with an overall fluid and electrolyte depletion, and should be corrected preoperatively. Obstructive jaundice classically causes a prolonged PT, which may reverse with administration of vitamin K.

Warfarin anticoagulation can be either partially or fully reversed, depending on the thrombotic risk to the patient. When the thrombotic risk is extremely high, the patient is converted to intravenous heparin anticoagulation for easier control (see below). There is time for insertion of an inferior vena caval (IVC) filter if this is indicated.

If a patient has had no effective oral intake in the week before surgery, and a gastrointestinal operation is planned after which oral intake will be further delayed, the institution of IV feeding before surgery may be beneficial.

The 4-week window

Most cancer surgery can be delayed for several weeks, without detriment. This allows better medical control of severe hypertension or other cardiorespiratory pathology. There is also time for benefit to accrue from the cessation of smoking. Occasionally, this window must be utilised for the surgical correction of another pathology which, if uncorrected, will make surgery more hazardous. For example, a carotid endarterectomy will greatly reduce the incidence of an intraoperative stroke in a patient with a severe carotid stenosis who requires another major procedure. Iron deficiency anaemia can be corrected, reducing the need for perioperative blood transfusion, and contraceptive pill or aspirin therapy can be stopped with normalisation of the risk of thromboembolism or operative bleeding. There is also time to plan the management of patients on anticoagulants and those who have a greatly increased thrombotic risk (see below).

The over-4-month window

Truly elective surgery should be postponed if the risk of surgery is significant and can be reduced with the passage of time, or when some medical or surgical prior intervention will reduce the overall risk. During the first 6 months after a myocardial infarct the risk of a further infarct in the perioperative period is increased by 30 per cent. A delay of at least 6 months should be observed if the underlying condition will not deteriorate significantly during this period. The risk of a further stroke after a cerebral vascular accident is also increased, and a similar delay is recommended. Grossly overweight patients can sometimes manage a significant weight reduction, but more often they are unsuccessful. It may be appropriate to delay surgery until after a carotid endarterectomy, a cardiac valvular replacement, an aortic aneurysm repair, a coronary bypass graft or angioplasty if it is felt that this will reduce the overall mortality or morbidity.

PATIENT INFORMATION AND 'CONSENT'

The regular guidance on 'informed consent' given by the General Medical Council and various defence organisations is extremely helpful, especially as misconceptions persist. The surgeon must discuss with the patient alternative management strategies and the benefits and complications of any operation. The balance is difficult and, in attempting to correct the previous paternalistic approach, surgeons have left some patients feeling vulnerable and ill-equipped to make the choices now expected of them. All patients must, however, understand the aims, limitations and risks of the surgery they are to undergo, and have the opportunity to ask for more information if they wish. Trust remains important, because when a complication arises it is easy for the patient to believe a mistake was made or that the surgeons did not try their best.

Surgery that alters body image (amputation of a limb, mastectomy or the formation of a stoma) can be particularly distressing. Preoperative counselling by a specialist nurse, patient information leaflets and a visit from a former patient who underwent similar surgery may all be helpful.

GASTROINTESTINAL PREPARATION FOR SURGERY

For any general anaesthetic the stomach should ideally be empty to reduce the risk of aspiration of gastric contents, especially during induction of, and recovery from, anaesthesia. In elective surgery, a period of 6 hours without food and 2 hours without clear fluids is normally requested by anaesthetists. In some emergency situations, however, surgery cannot be delayed for 6 hours. In addition, a patient with an intestinal obstruction will often not have an empty stomach, even if fasted and a nasogastric tube is in place. A patient who suffers limb trauma following a meal develops gastric stasis, and the stomach may remain full for many hours. In all of these situations the anaesthetist has to proceed with the increased risk of a full stomach, taking care to ensure that rapid intubation can be safely achieved.

Many surgeons have now abandoned bowel preparation except for low rectal anastomoses. Mechanical clearance of the colon can be achieved in the 36 hours before surgery by a variety of means, but oral proprietary preparations of ethylene glycol or sodium picosulphate have proved the most satisfactory. Most surgeons recommend a phosphate enema if full bowel preparation is not performed. Preoperative bowel preparation is not possible when there is an intestinal obstruction, and an intraoperative on-table lavage is an alternative (this is described in Chapter 23).

DIABETES

Diabetic patients should ideally have no residual long-acting insulin or oral hypoglycaemic agents affecting their blood glucose levels at the time of surgery. Conversion during the previous 24 hours to short-acting soluble insulin allows greater flexibility if blood glucose levels become labile. Most hospitals have a standard protocol for the management of diabetic surgical patients, but the insulin is usually given as a continuous infusion (1–3 IU/hour) and adjusted according to blood glucose levels. Conversion back to the original regime should await re-establishment of a normal oral food intake. Even after minor surgery the patient must be warned that there may be temporarily increased insulin requirements relating to the stress response and increased steroid production.

Emergency surgery on diabetic patients is often complicated by poor diabetic control and failure to recognise and treat hypoglycaemia or ketoacidosis perioperatively may have disastrous consequences.

STEROID THERAPY

Preoperatively, a patient may be unable to continue with their oral steroid regime because of restriction of oral intake or poor absorption. An alternative parenteral steroid must be substituted. Patients on long-term steroids, whether as replacement therapy or at therapeutic dosage, have suppressed adrenal glands and are unable to mount the normal steroid response to stress. Perioperatively, both groups should receive parenteral hydrocortisone, which is then maintained during the postoperative period, initially parenterally and later orally. On the day of surgery, 100 mg of hydrocortisone is given 1 hour before surgery, and a further 100 mg every 8 hours. The dose is reduced as the stress from surgery diminishes until finally the preoperative dose is achieved. Even after relatively minor surgery, increased levels are required for several days and, after major procedures, often for over 2 weeks. Too rapid a reduction is unphysiological and leaves the patient at best tired and depressed and at worst with a full-blown hypotensive addisonian crisis.

THYROTOXICOSIS, PHAEOCHROMOCYTOMA AND CARCINOID SYNDROME

High levels of circulating thyroxine, adrenaline, noradrenaline or 5-hydroxytryptamine (5-HT, serotonin) can result in a patient developing extreme cardiovascular instability during anaesthesia. The situation is compounded in surgery to remove a hormone-secreting tumour or overactive gland, when surgical manipulation can cause sudden bolus release into the circulation of the active hormone. However, the diagnosis in these patients is usually already established, and the effects of the abnormal secretions can be blocked pharmacologically prior to surgery. The greatest surgical risk is in patients in whom the diagnosis has not been made preoperatively and who may be undergoing unrelated surgery.

BLOOD CLOTTING AND SURGERY

Thromboembolic prophylaxis

Deep venous thrombosis (DVT) and pulmonary embolus (PE) following otherwise successful surgery remain significant causes of postoperative mortality and morbidity. Stasis, hypercoagulability and intimal damage are all implicated in the pathophysiology. The incidence can be reduced by assessment of the risk in each patient and the institution of physical and pharmacological preventative measures appropriate to the level of risk. A scoring system, in which various risk factors carry different weighting, can divide patients into low-, moderate- and high-risk groups.

The most important general risk factors for thrombosis include a personal or family history of DVT or PE, known hereditary thrombophilia, immobility, increasing age, obesity, pregnancy and the combined contraceptive pill. Severe infection, inflammatory bowel disease and underlying malignancy also increase the risk of thrombosis. Major additional risk factors relate to the magnitude of the operation and the immobility associated with it. In particular, trauma and surgery to the hip, pelvis and lower limb are associated with increased risk.

Preventative strategies can be divided into physical measures that help to prevent stasis and pharmacological measures to reduce the coagulability of the blood. Early mobilisation and graduated compression stockings after surgery are important in preventing postoperative stasis, but most thromboses develop during surgery. A variety of mechanical devices that cause intermittent calf compression, either by direct external pressure or by initiating calf muscle contraction with intermittent foot impulse, are available in the operating theatre.

Heparin prophylaxis is the most widely used pharmacological measure. Low-molecular-weight heparins have the advantage of a longer half-life, allowing a single daily dose. The regime is normally started before surgery but for certain procedures, including epidural anaesthesia, it may be reserved until after completion of surgery if there is concern that it may increase haemorrhagic complications.

Early mobilisation and graduated compression stockings are all that is recommended in low-risk patients. In patients with a moderate risk of thrombosis, either heparin or intermittent foot impulse is added to the prevention regime, whereas in high-risk patients the two strategies can be used in combination. Additional measures such as an IVC filter and extended warfarin prophylaxis should also be considered.

Abnormal clotting associated with another disease

- *Platelet production* may be depressed in any patient with a haematological malignancy or in any patient with marrow depression from cytotoxic drug therapy or alcohol. Malignant marrow replacement can also suppress platelet production. A platelet count is important preoperatively in patients in whom a depressed count is likely. A normal count does not always reflect normal function.
- *Platelet destruction* in idiopathic thrombocytopaenia is the most common scenario in which a surgeon has to operate on a patient with a low platelet count, as a splenectomy may be required when other treatment modalities have failed. Platelet infusions may be required to cover the period of surgery, but it must be remembered that the half-life of platelets in this condition is very short. Platelets for transfusion are prepared from several donors, and have a shelf-life of 5 days. They must be ABO compatible (see Appendix II, p. 529).
- *Obstructive jaundice* results in prolonged clotting from poor production of clotting factors secondary to a deficiency of vitamin K. It is reversed by administration of vitamin K a few days preoperatively.
- *Liver failure* also results in prolonged clotting from poor production of clotting factors by the failing liver. Vitamin K may not be effective. Surgery will be very high risk and clotting abnormalities have to be treated with fresh-frozen plasma transfusions and/or cryoprecipitate.
- *Inherited defects of clotting*, such as haemophilia (Factor VIII deficiency), Factor II deficiency and von Willebrand's disease, may affect up to 5 per cent of the population. Communication in advance with the haematologist is the key to the planning of safe surgery. The presence of inhibitors in the patient's serum requires more complex replacement of clotting factors, with vigilant specialist monitoring.

Management of patients on anticoagulation therapy

Management of anticoagulation during the perioperative period is dependent on the indications for therapeutic anticoagulation, the thrombotic risk of the patient and the haemorrhagic risk associated with the surgery. Surgery on a fully anticoagulated patient is likely to be complicated by bleeding, and anticoagulation should be reversed before all elective surgery unless the risk of clotting is extremely high. For the majority of patients on warfarin, this can be safely stopped 3 or 4 days preoperatively and the clotting should have returned to near normal by the time of the operation. The International Normalised Ratio (INR) is checked immediately preoperatively; it should be less than 1.8 even for minor surgery and 1.4 is a safer target. Warfarin can be restarted once the risk of early postoperative bleeding has passed. After minor surgery patients can return to their normal drug regime the day after surgery, and therapeutic levels will gradually be restored over several days. More urgent reversal of warfarin anticoagulation can be achieved with low-dose intravenous vitamin K, which takes around 6 hours. This is combined with fresh-frozen plasma or a clotting factor concentrate when there is greater urgency or when a patient is over anticoagulated.

Patients with a high risk of thrombosis – for example, those with a recent personal history of thrombosis, thrombophilic factors and mechanical heart valves – should have a protocol tailored to their needs by liaison with a haematologist. There is a delicate balance between thrombosis and surgical haemorrhage that needs to be assessed. Conversion from warfarin to heparin anticoagulation is usually instituted, as the effects of heparin can be quickly reversed, enabling the patient's coagulation status to be managed perioperatively more safely. The infusion of non-fractionated, short-acting intravenous heparin is simply stopped 1 hour prior to the surgery itself. The half-life is only 1.5 hours, but if more rapid reversal becomes necessary, then protamine can be given. Cooperation is essential between surgeon, anaesthetist, cardiologist and haematologist in managing these high-risk patients.[3]

An IVC filter may be considered, but will only protect against a pulmonary embolus. It does not prevent a deep venous thrombosis or the complication of thrombus formation on a prosthetic heart valve, within the atria or in an arterial graft. The IVC filter is usually inserted by a radiologist a few days before surgery.

An increasing number of patients are on low-dose aspirin for prevention of thromboembolic events. Aspirin and other anti-platelet agents produce an irreversible platelet dysfunction, and haemostasis can only return to normal as new platelets are formed. Therefore, if these agents are to be discontinued prior to surgery, at least a week must elapse for platelet activity to improve significantly. Stopping aspirin significantly increases the probability of perioperative cardiac events in at-risk patients, and this often outweighs the increased risk of bleeding.[4]

INTRAVENOUS ACCESS

Peripheral vein access is adequate for the administration of fluid, blood or drugs. The hypertonic solutions for parenteral nutrition are irritant to endothelium and in a narrow-calibre vein, with small volume flow, cause early phlebitis and vein occlusion with adherent thrombus. Central venous access is therefore usually established when hypertonic irritant fluids or drugs have to be administered intravenously. It is also required for the measurement of central venous pressure. Although long catheters can be threaded centrally from peripheral veins, direct cannulation of the subclavian or internal jugular vein is preferable.

Percutaneous peripheral vein cannulation

The veins on the dorsum of the hand and forearm are the most suitable. The needle with the overlying plastic cannula is introduced into a vein, the needle withdrawn and the plastic cannula advanced up the lumen of the vein and strapped in place. A cannula that crosses a joint may occlude when the joint is flexed and in addition, movement results in increased trauma to the endothelium. The prominent superficial veins in the antecubital fossa, although ideal for emergency access, are therefore less suitable for longer-term cannulation. The use of leg veins should be avoided as cannulation will restrict mobility and may increase the risk of DVT.

The 'lifespan' of peripheral cannula access is extremely variable. Once any phlebitis or fluid extravasation develops, occlusion is inevitable and the cannula should be replaced in another vein. To await the inevitable occlusion risks a severe local reaction and the occlusion of adjacent segments of vein, which will not then be available for later cannulation. In addition, there is a significant risk of septicaemia. The lifespan of a cannula will be greater if it is inserted using an antiseptic technique and if endothelial irritation from hypertonic solutions is minimised. Mechanical trauma from movement can be reduced if the vicinity of joints is avoided, and a small cannula in a large vein causes less endothelial trauma. However, a small cannula is inappropriate in patients who may require rapid replacement of fluid or blood.

Peripheral vein 'cut down'

This technique can produce rapid, large-diameter, secure intravenous access. It may be appropriate in a shocked patient in whom peripheral veins are collapsed and difficult to enter and central catheterisation skills are unavailable or have failed. Peripheral vein 'cut-down' also provides secure intravenous access for several days, which can be difficult to achieve, especially in a small child, if appropriate plastic cannulae or intravenous infusion needles are unavailable.

A transverse incision is made over a vein. The subcutaneous tissue is opened by sharp or blunt dissection on either side of the vein until an artery forceps can be passed beneath it and used to draw a ligature round under the vein. This ligature is then tied as far distally as possible, and a second ligature passed beneath the vein more proximally. The second ligature is left untied until the cannula is in place. A small incision is made between the ligatures, the plastic or metal cannula inserted and the second ligature tied to hold the vein snugly against the outside of the cannula. In a small child the long saphenous vein at the ankle is the most suitable, as the risk of DVT is not a consideration and this vein is of large calibre and anatomically in a standard position.

Interosseous access

Interosseous access was a common route for infusion of blood or fluids in the early years of the twentieth century. It fell into disuse as intravenous techniques improved, but regained popularity during the 1990s as the fastest route for circulatory access in a young child. The most suitable site is the anteromedial surface of the proximal tibia, 1–3 cm below the tibial tubercle. An 18–20-gauge needle is satisfactory in babies, but over 1 year of age a 13–16-gauge is more suitable. The needle should be stiff so that it does not break on insertion into bone, and have a stylet to prevent marrow plugging the lumen during insertion. The needle is inserted at an angle of about 15 degrees from the perpendicular, away from the tibial growth plate, and the stylet removed. This technique is also possible in adults, but a drill is required. The technique is not without its dangers and distal limb gangrene has been reported.[5]

Central venous catheterisation

Central lines are used with increasing frequency in surgical patients. Peripheral thrombophlebitis from mechanical and chemical irritation is reduced and the lifespan of access greatly increased. Multi-channel lines, with two to five channels, allow monitoring of central venous pressure through one channel, continuous administration of intravenous fluids through a second and infusion pump administration of insulin, heparin or an inotrope through a third. Further channels can then be used for bolus administration of drugs and removal of blood samples.

These lines may be inserted after induction of anaesthesia as part of perioperative anaesthetic care, or they can be inserted in the conscious patient either pre- or postoperatively. Ultrasound guidance reduces the risks and should be used when available. Sterility is mandatory if infective complications are to be minimised. The patient is placed supine and tilted 15–30 degrees head-down to fill the veins of the neck and the superior mediastinum. There are multiple commercial kits for cannulation, but all are based on initial entry into the vein with a needle followed by manoeuvres to advance a long catheter safely into the superior vena cava (SVC). It is dangerous to advance the catheter through a needle, as in this technique the needle can cut the catheter, with a resultant embolus of the catheter tip. In the *Seldinger technique* a flexible guide wire is inserted down the needle. The needle is then removed and a long catheter advanced over the wire, which is finally removed. Intermediate dilating cannulae may be used over the wire if a large-bore catheter is required. An alternative to the Seldinger technique is to use a needle and cannula together for the initial venous insertion. The needle is withdrawn and a long catheter can be threaded safely through the cannula. An initial small skin incision is essential if any catheter is to be threaded over a wire, otherwise the catheter cannot be passed through the skin. In the conscious patient, a bleb of local anaesthetic is infiltrated in the skin followed by deeper infiltration onto the vein.

Central lines are not without complications. Insertion can be associated with a pneumothorax or, occasionally, a major haemorrhage. The tip may be advanced too far and cause arrhythmias or may turn up into the jugular veins from a subclavian insertion. An X-ray immediately after insertion is therefore essential. Infection of a central line commonly presents with septicaemia, but thrombophlebitis and occlusion can also occur. Full sterile precautions for insertion are therefore mandatory. An infected line must be removed and important access is lost. Multi-channel, multi-purpose lines unfortunately are prone to infective complications unless all personnel using them observe similar strict precautions. Single-channel dedicated lines are therefore used when long-term access is required for prolonged intravenous feeding or the administration of cytotoxic drugs.

Internal jugular cannulation

Internal jugular cannulation is favoured by anaesthetists, but the position of the cannula is awkward for the conscious patient. The head is turned to the opposite side. The surface marking of the vein is from the ear lobe to the medial end of the clavicle. The vein is overlapped by the sternocleidomastoid muscle, but is often palpable in the lower one-third where it lies between the sternal and clavicular heads of the muscle. The carotid artery lies posteromedial to the vein. The fingers of the left hand retract the carotid artery medially, and skin entry is at the apex of the triangle formed by the confluence of the two heads of sternocleidomastoid. The needle is slanted at 30 degrees to the skin and advanced caudally. Resistance is felt, then lost, as first deep fascia is encountered followed by vein wall.

Subclavian vein cannulation

Subclavian vein cannulation is the most satisfactory long-term central venous access. The vein runs horizontally behind the clavicle to join the internal jugular vein behind the sternoclavicular joint. It is closely related to the subclavian artery, and the dome of the pleura with the underlying lung apex. These structures may be injured during insertion of a subclavian line. A sandbag is placed under the upper thoracic spine so that the shoulders fall back, the arm is retracted downwards to depress the shoulder girdle and the head is turned to the opposite side. The needle is inserted 1 cm below the junction of the middle and outer thirds of the clavicle, and is angled so that it passes deep to the clavicle in the direction of the ipsilateral sternoclavicular joint. Insertion on the right side is a more natural procedure for a right-handed surgeon, but on the left side it is often easier to advance the cannula into the optimum position as the angle into the SVC is less acute. When long-term cannulation is required, a subcutaneous tunnelled length of line, as illustrated in Figure 12.5 (p. 205) will reduce infective complications.

Peripherally inserted central catheters

Peripherally inserted central catheters (PICCs) are long catheters inserted into a peripheral vein and advanced through to the central veins. Although these fine catheters are unsuitable for central venous pressure monitoring, they provide good long-term central venous access.

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PATIENT SAFETY

Patient safety can be summarised by the old adage – "first do no harm". It encompasses the whole of medical and surgical practice and must be in the forefront of surgeons' minds throughout their care of a patient. In the outpatient clinic it could include the avoidance of unnecessary and potentially harmful investigations in a frail elderly patient in whom surgery is not an option even if a malignancy is confirmed. In pre- and postoperative hospital care, patient safety encompasses a range of issues from the documentation of drugs to which the patient is allergic to whether a bed has been pushed against a dangerously hot radiator. However, it is in the operating theatre environment that patient safety is the biggest issue for surgeons and anaesthetists. In addition to the topics discussed below, many checks have been put in place to prevent the tragedies of mistaken patient identity and the wrong patient receiving an operation and the equally devastating mistake of an operation performed on the wrong side. The reporting and analysing of adverse events and 'near miss' situations in order to prevent their recurrence is an important dimension of patient safety.

ANAESTHESIA

For almost all surgery some form of general or regional anaesthesia is essential. Except for local infiltrative anaesthesia, this is primarily the responsibility of the anaesthetists, who also have the maintenance of all the patient's vital functions under their control during the operation. The anaesthetist will choose the most appropriate anaesthetic, but often only after discussion with the surgeon, as the planned position of an incision or the expected length of a procedure may influence the decision. In addition, the surgeon may require specific intraoperative conditions – for example, abdominal muscle relaxation or low central venous pressure.

Local infiltrative anaesthesia

Local infiltrative anaesthesia is the standard technique for all minor surgery on the skin or subcutaneous tissue. It can also be used for more major procedures such as inguinal herniorrhaphy, but care must be exercised that toxic doses are not exceeded (see Chapters 2 and 25). Local anaesthetic toxicity requires immediate action, including the management of convulsions, arrhythmias and cardiac arrest. The cardiac effects can be resistant to treatment, but the addition of an infusion of Intralipid® 20% (1.5 mg/kg) has proved of value and should be kept readily available for such an event.[1] Handling of the peritoneum or spermatic cord can cause bradycardia, hypotension or vomiting. It is important, therefore, that patients having this type of surgery are fasted and monitored and that the assistance of an anaesthetist is immediately available if required. This is particularly important when local anaesthesia has been chosen for an elderly patient who has cardiovascular co-morbidity. Apprehension or pain will increase both metabolic requirements and adrenaline output, and arrhythmias, angina and acute ventricular failure may be precipitated. A combination of sedation and local anaesthesia can be particularly dangerous in such patients. Oversedation can result in confusion, but sedation then has to be increased further for the surgeon to complete the operation on a confused uncooperative patient. Finally, the surgeon can be operating on a semi-anaesthetised patient, with significant cardiac or respiratory co-morbidity, without either adequate monitoring or airway protection.

Peripheral nerve blocks

Lidocaine without adrenaline is infiltrated around a nerve to anaesthetise the tissues it innervates. Direct puncture of the nerve is not only extremely painful, but may cause axonal damage. A good knowledge of anatomy is essential, as major vessels are often in close proximity to major nerves and are in danger of injury. Further reading is recommended for surgeons who are interested in this technique for anything other than digital or intercostal nerve blocks.[2]

Epidural and spinal regional anaesthesia

If possible, an anaesthetist should be responsible for epidural and spinal regional anaesthesia. They cannot be easily instituted, monitored and adjusted by the surgeon, although the occasional isolated surgeon practising in an area with limited healthcare resources has to compromise. The surgeon establishes the epidural or spinal anaesthetic and then leaves the patient partially under the care of an assistant while proceeding with the surgery, but with continuing overall responsibility for the anaesthetic issues as well.

Regional intravenous anaesthesia

Also known as a Bier's block, regional intravenous anaesthesia is a simple technique for distal limb anaesthesia and useful for the setting of a displaced wrist fracture. A cannula is inserted into a distal vein and the limb exsanguinated either by bandaging or, if too painful, by elevation. A proximal tourniquet is inflated and a dilute solution of prilocaine injected through the cannula into the isolated veins. A dose of 4 mg/kg should not be exceeded, but the volume must be sufficient to fill the veins, and around 40 ml will be required for an adult arm. After 5 minutes, sufficient anaesthetic agent will have infiltrated out into the tissue to allow manipulation of the fracture. After 20 minutes, almost all of the anaesthetic should have diffused out of the vessels into the tissues and the cuff can be safely deflated. The simplicity of this technique encouraged surgeons to use it themselves in accident departments. Unfortunately, premature deflation of the tourniquet, for whatever reason, floods the circulation with a large bolus of local anaesthetic, with serious and even fatal cardiovascular and CNS toxicity. It is therefore considered a potentially dangerous technique, and it is now recommended that, ideally, it should only be used by anaesthetists who will be more able to deal with complications should they occur.

General anaesthesia

For most major surgery general anaesthesia is the ideal anaesthetic. Inhalational or intravenous drugs, or a combination of these, are used to keep the patient in a state of unconsciousness for the duration of the surgery. Patients may be breathing spontaneously or may be paralysed and mechanically ventilated, but with either technique they are unable to protect their airway, which is vulnerable to obstruction by the tongue or from inhalation of vomit or secretions. Laryngeal masks are now used routinely but, if unavailable, a face mask and oral 'airway', combined with skilful holding of the lower jaw forwards, will also suffice. However, only an endotracheal tube gives reliable protection against inhalation of secretions or gastric contents.

Ketamine has proved to be an extremely safe agent where anaesthetic skills are limited. It provides a state of 'disassociative anaesthesia' – a profound analgesia with light sleep – and surgery is possible on a patient who can still protect his or her own airway. Slow recovery and unpleasant hallucinations have restricted its more general use.

PATIENT POSITIONING

An anaesthetised patient is unable to protect joints from excessive damaging movement and if the patient has to be turned, particular attention to the neck is important. Arms may become trapped or fall unsupported and, in general, during repositioning they should be held straight and adducted alongside the patient's trunk. Legs that have to be elevated should be moved together to prevent an uneven strain on the lumbar spine. An unstable position may be necessary to allow the surgeon satisfactory access, and the patient must be made secure in, for example, a lateral position, with the upper arm supported, and the table 'broken'. The ideal position for the surgeon may not be satisfactory for an anaesthetised patient. For example, abduction of the arm should be kept to less than 90 degrees and, if legs have to be elevated for a long procedure, extreme flexion of knees and hips should be avoided (see Figures 24.3a and b, p. 438). It should be remembered that patients who have regional anaesthesia are equally vulnerable in the paralysed and anaesthetised areas. Even a Lloyd–Davies position can compromise perfusion of the legs in a very long operation, and a postoperative calf compartment syndrome is a well-recognised, but fortunately rare, complication. Consideration must be given to mechanical prophylaxis of deep venous thrombosis (see Appendix I).

The most vulnerable area of skin is that on which the patient is lying. The initial ischaemic insult in a postoperative sacral or heel pressure sore has most often occurred during the surgery itself. Pressure damage can be reduced by the use of a soft surface, a 'jelly mat' or a sheepskin, and heel pressure can be further reduced by spreading the area of weight-bearing skin with a soft support under the Achilles tendon. It is also important during long operations to tip the table in different directions to alter the pressure points. Localised pressure from restraining straps, armrests and lithotomy poles can also cause pressure damage to skin or to a superficial nerve. The ulnar and the lateral popliteal nerves are the most vulnerable. No skin should be in contact with any metal part of the operating table or its attachments, or there is a danger of a diathermy burn. The eyelids must be kept closed to protect the cornea from drying and abrasions.

MONITORING DURING SURGERY

In all surgery under general anaesthesia the surgeon is only marginally involved in the monitoring of the patient's overall homeostasis. The anaesthetist will, however, need to know whether measurements of urine output or blood loss are realistic. Ascitic fluid, mixed with blood and weighed in swabs, may be erroneously recorded as blood, and in open genitourinary surgery urine output may significantly exceed the urine collected by catheter. A surgical observation that the blood pooling in the pelvis is no longer clotting often predates confirmation of a clotting abnormality on laboratory tests.

In minor surgery under local infiltrative anaesthesia, no monitoring may be necessary but, when a surgeon is operating on an elderly unfit patient for a more major procedure, monitoring is desirable. An ECG, pulse oximetry and blood pressure monitoring are straightforward to set up and may alert the surgeon to a deteriorating situation. The patient should also have an intravenous cannula in place in case emergency intravenous access is required.

Intraoperative imaging

X-ray monitoring is routine in many urological, orthopaedic, vascular and biliary procedures. A single exposure can demonstrate the position of a fracture after reduction or can confirm the free flow of contrast along a vessel, a duct or a ureter on which surgery has been performed. An image intensifier allows surgery to be performed with continuous radiological screening to guide the passage of the tip of an instrument that is not visible or palpable by the surgeon. Inappropriate or excessive X-ray exposure of both patient and staff must be avoided. The guidelines for safe practice are strict, but must be observed.[3] Intraoperative ultrasound does not pose these safety hazards, but is not universally appropriate.

PREVENTION OF INFECTION

Sterilisation of instruments and the use of antiseptic skin preparations, sterile drapes and towels do not ensure total sterility. Bacteria are released into the operating theatre air from the skin and respiratory tract of everyone present in the theatre. Masks prevent droplet contamination of the wound if a surgeon sneezes, but are largely ineffective in reducing the general contamination of the air with organisms. Decontamination of the surgeon's hands and forearms by an antiseptic wash, followed by wearing of a sterile surgical gown and gloves, is no longer an effective barrier if a non-permeable gown becomes soaked with body fluids or gloves are torn. Preparation of the patient's skin in the operation field with antiseptic does not destroy the bacteria in the hair follicles or sweat glands. These bacteria may come to the surface with secretions during surgery. Sterile drapes over unprepared skin are not an effective barrier if they are permeable and soaked with body fluids. Surgery that opens the gastrointestinal tract is always contaminated.

Surgery should be undertaken in as clean an environment as is possible. Floors and surfaces should be washed and shoes and outer clothing changed. Controlled air flow can also reduce the bacterial count in the air. Sterile instruments, sutures and surgical gloves are used, and any skin not treated with antiseptic is isolated from the operative field by sterile drapes.

'Scrub' procedure is the antiseptic wash of the hands and forearms of those involved in the surgery. The traditional abrasive scrub is no longer recommended, as it damages skin and increases infection. Hands are simply washed in a detergent solution containing added chlorhexidine or an iodine-based antiseptic. Alternatively, an alcohol rub of already clean hands can be employed.

Skin preparation of the operation site with an antiseptic solution is standard. Suitable solutions again include iodine-based antiseptic solutions and chlorhexidine in water or spirit. Spirit-based solutions should be avoided or used with great care if diathermy is to be employed, as ignition of spirit-soaked drapes and of puddles of spirit in the vagina or umbilicus has been reported. Hairs obscure the surgeon's view and shaving of hair-bearing skin is standard. It does not, as originally believed, reduce infection and may, if carried out more than a few hours before surgery, increase the bacterial colonisation of hair follicles.

Sterilisation of instruments

Initial sterility of instruments is mandatory to prevent patient-to-patient spread of virulent organisms. (Instruments open to the theatre air will no longer be totally sterile at the end of a long operation.) Sterility can be achieved by destruction of bacteria and viruses by thermal, chemical or irradiation damage. The resistance of some organisms to all methods of sterilisation is greater than others, and it is on the properties of these organisms that sterilisation schedules have to be based. The choice of method employed is most often dictated by the properties of the material or instrument to be sterilised. Heat-tolerant materials and instruments can be sterilised by pressurised steam. The higher the temperature, the shorter the time that the temperature must be held for sterilisation, and several alternative cycles are available in standard autoclaves. The cycle commences with vacuum extraction of air, except in the small, portable steam sterilisers. The latter may therefore fail to sterilise an instrument with a lumen in which air is trapped and steam fails to enter. Heat without steam is less effective, and temperatures of 180°C for 60 minutes are required. Commercially, ethylene oxide gas and irradiation are used to sterilise single-use instruments and equipment. Instruments such as fibreoptic telescopes are damaged by the temperatures necessary for steam sterilisation. Formaldehyde or glutaraldehyde in an aqueous solution is the most common alternative used in hospitals for multi-use heat-intolerant equipment. Unfortunately, this will not kill all spores and viruses and must be regarded as a disinfection rather than a sterilisation procedure.

Antibiotic prophylaxis

Despite all the above measures, infective complications remain a significant source of postoperative morbidity in some procedures unless prophylactic antibiotic therapy is employed. The therapy is based on the concept that bacterial contamination occurs during surgery and that the administration of the antibiotic used for prevention must be timed for optimum blood levels during the operation.

Bacterial contamination of the blood may progress to bacteraemic shock or to infective vegetations, either on damaged heart valves or on the vascular anastomoses between native vessel and a prosthetic arterial graft.

Bacterial contamination of collections of blood or body fluid introduces organisms to an excellent culture medium, and abscess formation frequently follows. The administration of antibiotics once an abscess has formed is seldom sufficient definitive treatment. However, the complication can be prevented if there are high concentrations of antibiotic in these collections, making them an unfavourable culture medium. Antibiotic prophylaxis should therefore be administered immediately before, or during, surgery. Further prophylaxis for 48 hours postoperatively is justified if oozing of blood or tissue fluid from internal raw surfaces is expected to continue during this period. The choice of antibiotic is dictated by the likely pathogenic contaminants.

Patients at increased risk

Particular attention should be focused on patients who may be immunocompromised, whether by treatment with immunosuppressants or chemotherapy or because of the underlying pathology; for example, HIV infection, previous splenectomy or a haematological malignancy. It must be remembered that in patients with haematological malignancy a normal WBC count does not guarantee normal function and, in addition, repeated splenic infarction in sickle cell disease or a myeloproliferative disorder can result in hyposplenism from autosplenectomy. A second group of patients who require particular attention are those who are at increased risk of developing infection in a prosthetic joint, a vascular graft or on damaged or prosthetic heart valves.

Anti-staphylococcal prophylaxis

Anti-staphylococcal prophylaxis is most often considered in ‘clean’ surgery. The source of infection may be the patient’s own skin or upper respiratory tract or that of personnel in the theatre. The incidence of infection is low in clean surgery, but antibiotic prophylaxis is recommended if foreign material is used, as infection of a joint prosthesis, an arterial graft or the mesh in a hernia repair can all have disastrous consequences. The emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) has posed increasing difficulty in offering effective anti-staphylococcal prophylaxis without inappropriate use of ‘second-line’ antibiotics, which should be reserved for the treatment of severe infections with resistant organisms.

Intestinal organisms

Intestinal organisms include a wide range of potential pathogens, many of which are anaerobic. Antibiotic prophylaxis is recommended for all surgery in which the gastrointestinal tract is opened and is of particular importance in colonic surgery. A combination of broad-spectrum antibiotics that are effective against gram-negative organisms and anaerobes is commonly employed. The anaerobic clostridial organisms are commensals of the colon and encountered in the soil. Penicillin provides effective prophylaxis against gas gangrene and tetanus, and the risk should be remembered in contaminated wounds, especially if there is muscle ischaemia. Penicillin prophylaxis is recommended for all lower limb amputations for ischaemia.

Urology

A transient bacteraemia is common in urethral instrumentation, even of an apparently non-infected urinary tract, and occasionally progresses to bacteraemic shock. This serious complication can be almost eliminated by a single dose of gentamicin.

Endocarditis

The risk of endocarditis is greatest in patients with cardiac valvular lesions or a cardiac valve replacement, but prosthetic vascular grafts are also vulnerable. At-risk patients require antibiotic prophylaxis against possible pathogens. Anaerobic streptococci, which are sensitive to amoxycillin, are the most common pathogens, although other organisms can be implicated. Dental surgery therefore carries the highest risk, but any general anaesthetic can result in a bacteraemia with oral organisms including *Streptococcus viridans*. In gastrointestinal or urinary tract surgery, antibiotic prophylaxis should also cover gram-negative and anaerobic organisms, and gentamicin is given in addition to amoxycillin.

Viruses and prions

Viruses and prions pose a threat to the safety of all surgery. The long latent period before clinical symptoms and the serious and frequently fatal consequences of infection are major concerns. Hepatitis and HIV can be spread by small quantities of infected blood or tissue fluid, and it is mainly needlestick injuries that are responsible for infection between the operating personnel and the patient. Additional precautions, such as double-gloves and use of impermeable gowns, are commonly practised in a high-risk patient, but many carriers of these viruses are not identified. Great care should therefore be taken in the handling of needles and scalpels during every operation, and eye protection is also recommended. Diathermy for skin incision and dissection, the use of blunt needles for fascial closure and clips for skin closure can significantly reduce the risk by eliminating sharp instruments from the operation. All surgeons should be immunised against hepatitis B. Immunisation against hepatitis C and

HIV is not currently available, but HIV prophylaxis should be instituted after a needle-stick injury involving contamination from a known HIV carrier. Conversely, any surgeon who is a carrier of any of these viruses is a risk to patients and will probably have to cease operating. The prion responsible for new variant Creutzfeldt–Jakob disease (CJD) is not destroyed by normal sterilisation techniques and, although it is a rare disease, this knowledge has led to calls for single-use instruments for surgery. The financial implications of this for all surgery would be prohibitive, however.

Surgery for infective pathology

Antibiotics in this situation are given to treat rather than merely to prevent infection, and therefore must be given for an adequate period of time. A 5-day course is usually the minimum, but in certain situations relapse is common unless antibiotics are continued for 2 weeks or more. Broad-spectrum antibacterial activity is necessary until bacteriological results are available, and adequate blood levels can often only be assured with parenteral administration. In gastrointestinal infective pathology, prophylactic regimes of cephalosporin and metronidazole are often inadequate. Either gentamicin must be added to the regime or treatment with a broad-spectrum antibiotic such as Tazocin® (a piperacillin/tazobactam combination) substituted.

DIATHERMY

Haemostasis by diathermy coagulation has been available for over 50 years. Refinements in technology have led to the increased use of diathermy for dissection, with the advantage of greater precision in an almost bloodless operative field.

Monopolar diathermy

A high-frequency alternating electric current is passed through the patient. Heat is produced wherever the current is locally concentrated. A large plate electrode is held in contact with the patient's skin. The other point of patient contact is concentrated in a small area of tissue with a fine point or forceps, with resultant thermal damage. A *pulsed electrical output* has a coagulation effect. A *continuous output,* used to create an arc between the diathermy tip and the tissue, vaporises cell water and cuts tissue with minimal charring. A 'blend' of the two forms of current can provide the surgeon with a haemostatic cutting tip, which combines minimal charring with effective coagulation of small vessels.

In all monopolar diathermy there is a danger of burns from the wide plate if it is malpositioned and in contact with only a small area of skin. Burns may also occur if any part of the patient is in contact with earthed metal such as a drip stand. Current passes through the patient and although normally harmless, there is a risk in certain circumstances. Metal jewellery that a patient cannot remove may result in a local burn. Monopolar diathermy on an extremity with a narrow pedicle can result in a high concentration of energy in the tissue of the pedicle and thermal damage. The spermatic cord is thus at risk if diathermy is used on a testis that has been mobilised out of the scrotum, and urethral burns have been reported when monopolar diathermy was used during a circumcision. Diathermy current passing through a cardiac pacemaker can disrupt its function, and current can also be channelled along the wires and cause myocardial burns. The diathermy pad can sometimes be positioned to minimise the current through the pacemaker, but bipolar diathermy will be a safer alternative.

Bipolar diathermy

Bipolar diathermy is a less versatile, but safer, form of electric current haemostasis. There is no pad attached to the patient and the current only passes between the two tips of the diathermy forceps, coagulating the tissue held between them. Current will not pass from the tips along another instrument to the patient, and it therefore cannot be used to coagulate a vessel already held by ordinary forceps. Neither can it be used as a 'bloodless scalpel' for dissection, as no spark or arc can be created between the diathermy tips and the tissue.

Argon beamers

A jet of argon combined with a laser beam of electromagnetic energy produces a 'spray' effect, inducing coagulation in tissues a few millimetres from the tip of the instrument. The coagulation is very superficial, with minimal deeper thermal damage, and is a useful technique for large oozing surfaces such as a liver laceration or the remaining part of the spleen after avulsion of one pole.

BLOOD TRANSFUSION

Blood has been used in the treatment of haemorrhage since the early twentieth century. Patient attitudes to blood transfusion vary and specific preoperative consent is mandatory. The crucial development in safe transfusion was Landsteiner's discovery in 1901 of the major human ABO groups. Blood can now be separated into its components for individual use: red cells, platelet concentrates, fresh-frozen plasma, cryoprecipitate, albumin, high-purity factor VIII and combination factors are also available. This allows more targeted therapy. Preselection and screening of donors and donated blood for blood-borne pathogens is crucial. However, infection remains a hazard. Provision of safe blood requires a high level of organisation and strict protocol. If an accredited blood transfusion service is not available, avoidance of blood products, unless absolutely necessary, is extremely important. Unnecessary transfusions, such as occur when a preoperative anaemia could have been corrected or a drug associated with bleeding could have been stopped, must be avoided.

Blood banks

Where an accredited blood bank transfusion service is available this provides a safe source of blood for the surgeon who does not need a detailed knowledge of the collection, storage and compatibility testing of blood. However, it must be remembered that the most common cause of a serious transfusion reaction is either incorrect labelling of the blood sample sent from a patient for cross-matching or failure to ensure that the blood from the blood bank is administered to the correct patient. The importance of following all checking procedures in the ward or operating theatre cannot be overstated. Whenever possible, blood must also be ordered from the blood bank in time for all tests on antibodies and compatibility to be performed. The possibility that a blood transfusion may be needed during an operation should therefore be addressed preoperatively. If transfusion is unlikely, the patient's blood should be sent for grouping and antibody testing. If the patient does then need a transfusion, blood can be issued from the blood bank within 30 minutes with a high degree of safety. The presence of antibodies – more common after multiple previous transfusions – may require the pre-ordering of selected blood. It is rare to transfuse blood without some form of emergency compatibility test, but it is justified to transfuse non-cross-matched Group O Rhesus-negative blood in situations of massive blood loss. There is however, still the risk of a reaction to other antigens, especially in patients who have had previous transfusions.

Infection and blood

Blood collection must be performed using a sterile technique. A citrate anticoagulant solution is added, and the blood stored at 40°C. The shelf-life of blood is 35 days. Blood transfusion may transmit viral and protozoal infections in addition to bacterial infections. Protozoal infections that can be transmitted by blood include malaria, babesiosis, leishmaniasis, toxoplasmosis and trypanosomiasis. Viral infections potentially transmitted by blood include hepatitis A, B and C, cytomegalovirus, Epstein–Barr virus, human T-lymphocytotrophic virus, parvovirus B19 and HIV. As the red cell component of blood is not subject to sterilisation or virucidal treatment, donor selection and screening is crucial.

Transfusion reactions

A reaction during a blood transfusion may be one of pyrexia, shock or urticaria or of headache and backache. It is often not clear initially whether it is a haemolytic transfusion reaction, a more minor allergic or febrile reaction, a bacteraemia from contamination or an unrelated deterioration in the patient's condition. The initial management of all suspected reactions is discontinuation of the blood transfusion, followed by assessment. The blood bank should be informed immediately. During anaesthesia and surgery a transfusion reaction is more difficult to diagnose, as there are multiple other potential causes for a pyrexia, cardiovascular instability or allergic reaction.

- An *allergic reaction* is only rarely of a severe anaphylactic type requiring adrenaline and steroids. A minor reaction can be managed with antihistamines and continuation of the transfusion.
- A *febrile reaction* used to occur commonly, particularly with patients who had had multiple transfusions, due to sensitisation to platelet or leucocyte antigens. In the UK, leucocyte-depleted blood is now supplied, making this reaction uncommon. A red cell mismatch must be excluded.
- A *haemolytic transfusion reaction* to an ABO incompatibility is associated with a high mortality. It may commence after only a small amount of blood has been transfused. Shock, rigors and back pain are characteristic. The immediate dangers are of shock, hyperkalaemia and renal failure. Treatment is supportive resuscitation, and includes intravenous hydrocortisone and the maintenance of a good urine output. Dialysis may prove necessary.
- A *delayed haemolytic transfusion reaction* can result from minor blood group incompatibilities. Within a few days of the transfusion, the patient becomes jaundiced and anaemic with a low-grade fever. Treatment is supportive.

Autologous transfusions

Although some hazards of blood transfusion can be avoided by transfusion of the patient's own blood, this has not become common practice since it requires significant infrastructure to achieve successfully. There are three ways in which this can be achieved, but each has inherent limitations. Bacterial contamination and infection remain a risk.

- *Preoperative donation*, over a period of 5–6 weeks, can accumulate 2–4 units of the patient's own blood, which is available for transfusion at the time of surgery. The operation must be reliably scheduled and the patient must be fit to withstand repeated venesection without detriment. Oral iron and additional erythropoietin will help the patient recover a normal haemoglobin level more quickly.
- *Normovolaemic haemodilution* immediately before surgery consists of the withdrawal of 2 units of blood and replacement with three times the volume of crystalloid. The blood then available for transfusion is fresh with active platelets and clotting factors. It is

seldom possible, however, to withdraw more than 2 units in this way.

- *Intraoperative blood salvage* with reinfusion into the patient can be an excellent technique for conserving blood. It is sometimes used in an elective setting in knee surgery. In the emergency situation, massive haemorrhage into the peritoneal or pleural cavity is usually the only circumstance in which it is practical. It is not suitable if the blood is contaminated with gastrointestinal bacteria or with malignant cells. In its simplest form the blood is drawn into an evacuated container, containing citrate anticoagulant, and returned to the patient through a blood filter. The disadvantages of the technique in an emergency are the difficulties in setting up the collection of the blood on an occasional basis in a situation with exsanguinating haemorrhage. There are also the dangers associated with the infusion of activated clotting factors and of bacterial contamination. More sophisticated systems can wash and filter before reinfusion. This may be a *cell washer* in the theatre or the blood can be collected and taken to a central site for processing. The delays involved make these refinements less suitable in an emergency.

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APPENDIX III: POSTOPERATIVE CARE

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The main responsibility for postoperative care rests with the surgeon. The advantages of good surgery can be lost if such care is suboptimal.

LEVEL OF CARE

The appropriate level should be considered preoperatively and the decision reviewed at the completion of surgery if unexpected problems have been encountered.

Day surgery

Patients who are ambulant and who can resume normal oral intake within a few hours can return home. There should be no metabolic or cardiovascular instability and no respiratory compromise anticipated. Satisfactory pain relief must be possible with agents that are suitable for use at home. After a general anaesthetic, and after more major operations under local anaesthesia, patients must have a responsible adult who can care for them for the first 24 hours. The patient should be aware of the emergency management of any complication that might occur at home. However, if a complication would still be significantly more serious out of the hospital environment, the advisability of discharge home should be reconsidered.

Surgical ward

A surgical ward is an appropriate environment for patients who require nursing care, basic monitoring of vital functions and pain relief or other treatment that cannot be managed at home.

- *Nursing care* may include the management of open wounds and the challenges associated with urinary catheters, stomas, nasogastric tubes and chest or abdominal drains. Alternatively, it may be simply the basic care of an immobile patient.
- *Monitoring* of blood pressure, pulse, temperature, urine output and fluid balance are all standard ward procedures. Blood glucose can be monitored in diabetic patients and measurement of oxygen saturation and central venous pressure (CVP) is also practical. More advanced monitoring will require a more intensive environment.
- *Pain relief* with patient-controlled intravenous opiate or with an epidural infusion is impractical at home, but both can be managed in an appropriate surgical ward environment.
- *Other treatment*, although not practical at home, can be managed safely on an ordinary ward. Intravenous fluid replacement and parenteral feeding are straightforward unless the patient is cardiovascularly or metabolically unstable. Minor respiratory compromise can be treated with oxygen therapy and chest physiotherapy.

Intensive care or high-dependency environments

Intensive care or high-dependency environments are necessary when a patient is cardiovascularly unstable or has incipient, or established, respiratory or renal failure. The definition of these units varies in different localities, as does the balance of medical supervision. The surgeon, the anaesthetist or the medical intensivist may be the lead clinician, but the continued involvement of the surgeon remains important. Patients who require mechanical ventilation, inotrope support or dialysis are obviously candidates for this environment, but those in incipient cardiac, respiratory or renal failure will often have an improved prognosis if they can be transferred early to an environment where intensive monitoring and intervention are possible.

PAIN CONTROL

Pain after surgery is feared by patients, and control is important if only to avoid the distress it causes. In addition, uncontrolled pain delays recovery and increases postoperative complications. Pain from chest and upper abdominal incisions inhibits both adequate respiratory effort and the clearance of secretions. Control of pain reduces the incidence of postoperative chest infections. Pain after abdominal incisions is a potent factor in postoperative ileus, and the reduction of this complication in laparoscopic surgery is probably in part related to a reduction in abdominal wall wound pain. Pain is also associated with many of the troublesome postoperative nausea and hypotensive episodes that prevent satisfactory discharge after day surgery.

Oral analgesia

Oral analgesia is the mainstay for day surgery pain relief. A combination of a non-steroidal anti-inflammatory drug (NSAID) with a preparation of paracetamol and codeine proves satisfactory in most patients. Pain control can be improved by commencing analgesic drugs immediately prior to surgery. Patients in whom an NSAID is contraindicated will require an increased dosage of codeine. This may cause nausea and should be anticipated with an oral anti-emetic. Postoperative nausea and vomiting also prevent the satisfactory administration of oral pain relief.

Local anaesthetic infiltration

Local infiltration of bupivacaine into the wound provides excellent pain relief in the critical first 6 hours after surgery, and may be more effective if given at the start rather than the end of the operation. This technique is used extensively in day surgery, but is less effective in a long abdominal or thoracic wound where both superficial and deep anaesthesia are required. Further bupivacaine can be administered to prolong the anaesthesia if a wound catheter is left *in situ*.

Intramuscular opiates

Opiates are administered as bolus injections when required and were for many years the mainstay of postoperative inpatient pain relief. The patient frequently requires intramuscular or intravenous pain relief in the recovery area, and this is followed by further injections as necessary. This is still a satisfactory method in patients in whom only a few boluses are anticipated and who are expected to be ambulant and able to take oral medication within 24–48 hours. However, if severe prolonged pain is anticipated, this method is unsatisfactory as it produces widely fluctuating levels of pain relief, even with regular doses. Hourly boluses are safe if the patient is still in pain, but the situation must be carefully monitored to prevent overdosage.

Intravenous opiates

This is the fastest method of bringing severe pain under control. A 2.5 mg dose of intravenous morphine is safe for an adult in severe pain and can be repeated at 5-minute intervals, if necessary up to a total of 10 mg or more. Once the pain is under control, a longer-term plan for adequate pain relief can be instituted.

Patient-controlled analgesia

Patient-controlled analgesia (PCA) is a system of delivery of intravenous opiate, the dose of which is controlled by the patient. The patient can administer a bolus (usually 1 mg in adults) by pressing the control button. It should be possible for a patient to control pain without the risk of overdosage, as an oversedated patient will be too sleepy to press the button. However, it has been necessary to build various safety 'lock-out' devices into the system to prevent a rapid delivery of repeated boluses. A 5-minute period during which the system will not respond to a second request for a bolus is usually satisfactory. A further hazard can be button pressing by child visitors!

Epidural analgesia

Epidural analgesia is an extremely satisfactory method of ensuring a pain-free early postoperative period after major abdominal or thoracic surgery, without the sedation of systemic opiates. An epidural catheter is placed by the anaesthetist and analgesia is maintained by continuous infusion of local anaesthetic agents or opiates into the epidural space. The excellent pain control that ensues can reduce postoperative respiratory complications and enables the patient to turn and move more freely. Analgesia can be maintained without distal paralysis, and although the legs are frequently too weak for weight bearing, leg movement should still be possible. Epidural pain relief is, however, not without complications. Overdosage can be responsible for hypotension, and failure of delivery from a blocked or misplaced catheter can result in severe breakthrough pain, which is sometimes difficult to get under control. Infection in the epidural space is a potential disaster. Catheters must be sited under sterile conditions and precautions taken to prevent subsequent introduction of infection. An epidural catheter should be removed as soon as it is no longer in use, and its retention for over 3 days should generally be avoided. An epidural haematoma is a rare, but potentially catastrophic, complication. The signs of cord compression from an expanding haematoma may be mistaken for the effects of the epidural infusion until cord damage is irreversible. Management consists of early awareness of the possibility, confirmatory imaging and urgent neurosurgical transfer for decompression of the cord. Prevention includes good insertion technique and avoidance of epidural anaesthesia, or analgesia, in patients with an underlying clotting abnormality. Epidural catheters should not be inserted or removed within 12 hours of low-molecular-weight heparin thromboprophylaxis.

INTRAVENOUS FLUID REQUIREMENT

Despite enhanced recovery programmes (see Chapter 12), many postoperative patients remain unable to take oral fluids for several days. Intravenous maintenance requirements for adults and children are given in Table AIII.1. To this must be added fluid and electrolytes to correct pre-existing dehydration and to replace continuing abnormal fluid losses (see Chapter 12). In the early postoperative phase the correct volumes can be difficult to calculate.[1] In addition, fluid shifts may result in an imbalance with hypovolaemia in association with increased interstitial fluid. An adequate circulatory volume, CVP and urine output can then only be maintained by a positive fluid balance. Conversely, increased output of antidiuretic hormone postoperatively inhibits the excretion of excess intravascular fluid, and subsequent fluid overload, particularly in the elderly, can precipitate congestive cardiac failure.

In adult practice the maintenance fluid and electrolyte requirements are seldom calculated accurately according to weight. Instead, a standard regimen of 2–3 litres of fluid is

Table AIII.1 *Daily intravenous maintenance requirements for babies, children and adults.*

Water	Sodium	Potassium
100 ml/kg for the 1st 10 kg +50 ml/kg for the 2nd 10 kg +25 ml/kg for each subsequent 10 kg	1.5–2 mmol/kg	1 mmol/kg

given of which one-third to one-quarter is normal saline and the remainder 5 per cent dextrose. These solutions are available with potassium included (usually 40 mmol/l) but alternatively, potassium can be added in aliquots of 27 mmol. A small elderly patient would therefore receive as maintenance 500 ml of saline and 1.5 litres of 5 per cent dextrose, and a large younger patient 1 litre of saline and 2 litres of 5 per cent dextrose (Table AIII.2).

Table AIII.2 *Maintenance regimens.*

Body weight/ status	Total intake	Fluid	Sodium
40-kg elderly woman	1.5 litres dextrose 500 ml saline 54 mmol K^+	2 litres	70 mmol (1.5–2 mmol/kg)
80-kg young man	2 litres dextrose 1 litre saline 81 mmol K^+	3 litres	140 mmol (1.5–2 mmol/kg)

PARENTERAL FEEDING

Cardiac, respiratory and renal failure are all well recognised by clinicians as life-threatening conditions for which medical intervention is indicated to reduce mortality. Nutritional failure presents more insidiously, and although eventually equally serious, is often ignored. Starvation or nutritional failure is a contributory cause of death in many patients who die in hospital of complications some weeks after surgery. This was discussed in Chapter 12, as it is of particular relevance in gastrointestinal surgery. The simpler and more satisfactory option of enteral feeding should always be considered, and this is also discussed in Chapter 12. However, it may not be practical in the presence of gastrointestinal complications, and parenteral feeding has to be instituted.

Although oral intake of food comprises ingestion of large molecules of protein or starch, intravenous feeding is comprised of the molecules to which these foodstuffs are reduced in the gut before absorption into the circulation. Solutions of amino acids and glucose and emulsions of lipids form the basis of intravenous feeding. It is now standard practice to combine the lipids, glucose and amino acids in a single bag to which is added a customised amount of additional electrolytes, vitamins and trace elements. These bags (2.5 or 3 litres in adult practice) are prepared in the pharmacy under sterile conditions that minimise the septic complications from bedside additions to what is an excellent culture medium. The solutions used for parenteral nutrition are hypertonic and irritant to peripheral veins. A central venous line is therefore usually established (see Appendix I). Sterility is paramount, as infection causes septicaemia and central vein thrombosis. A feeding line should therefore be a dedicated line and not used for intravenous access for other purposes. For long-term feeding a length of line tunnelled subcutaneously can reduce septic complications and prolong the life of the line (see Figure 12.5, p. 205).

Energy

Food is the fuel for the body. Carbohydrate supplies approximately 4 kcal/g and fat 9 kcal/g. Fat, although apparently a more valuable fuel source, cannot be metabolised efficiently on its own. It is therefore still important to provide nutritional support to the obese patient. Protein is a fuel source that is sometimes neglected in calculations; it supplies approximately 4 kcal/g when broken down, with the release of nitrogen to be excreted as urea. Skeletal muscle is therefore an important source of fuel in the starved patient. However, some of the amino acids given intravenously during well-balanced parenteral nutrition should be destined for the replacement of enzymes and for structural repair. Fuel is required by every cell of the body for maintenance of its cell membrane function and also for essential mechanical and enzymatic functions within the cell. Proportionally more is required by cells that are performing vital metabolic functions for the whole body; for example, in the resting state the liver accounts for 26 per cent of the total basal metabolic requirements.

Specific nutrients

Food is essential for the provision of specific nutrients for chemical reactions and for structural intra- and extracellular materials. Amino acids are the most important building blocks of tissue, but lipids and carbohydrates are also required for structural mucopolysaccharides, glycoproteins and glycolipids. The balance of amino acids is important, in particular when feeding a very sick patient with an already compromised metabolism. Although an imbalance can to some extent be overcome by metabolic pathways that convert one amino acid to another, there are still problems. Some ‘essential’ amino acids cannot be manufactured by normal human metabolic pathways. Others, ‘conditionally essential’, can only be made in ideal metabolic circumstances. In addition, a poorly balanced combination places an additional strain on the patient’s already compromised metabolic pathways. Much of an excess amino acid is then often simply broken down and lost to the amino acid pool, and although some protein calories are extracted, the nitrogen must be excreted, placing further demand on suboptimal hepatic and renal function.

Daily requirements

The daily requirements of energy and specific nutrients are normally calculated according to body weight, although a calculation by lean body mass is probably more appropriate.

Basic energy requirements

These are of the order of 25–30 kcal/kg body weight per day (1,800–2,100 kcal/day for a 70-kg man):

- 1.5 litres of 20 per cent dextrose contain 300 g of glucose and will provide 1,200 kcal.
- 0.5 litres of 20 per cent lipid emulsion contain 100 g of lipid and will provide 900 kcal.
- Therefore, a combination will provide 2,100 kcal in 2 litres of fluid.

Protein requirement

This is estimated as approximately 1 g/kg/day (70 g/day for a 70-kg man), although 0.8 g/kg/day is usually sufficient (56 g/day for a 70-kg man).

- As nitrogen accounts for 16 per cent of protein, the requirement for nitrogen is approximately 9 g nitrogen per day for a 70-kg man (16% of 56 g = 9 g).
- 0.5 litres of amino acid solution can therefore complete the usual nutritional requirements within the daily fluid allowance.

Delivery of energy and protein requirements

Different concentrations of nutrients are available. The most frequently used formulations are compounded bags containing, for example, 9 g nitrogen/2,200 calories or 14 g nitrogen/2,400 calories.

Many postoperative patients in whom oral feeding is delayed due to a prolonged ileus only require a simple basic maintenance regimen, as outlined above, for a period of 1–2 weeks. The temptation to overfeed a severely malnourished patient must be resisted. Initially, their daily requirements are *less* and not more than the standard requirements. A process of '*reductive adaptation*' will have occurred. Enzyme reserves are reduced with increased cellular efficiency. A sudden increase in nutrients is beyond the metabolic capacity of the cells, and damage occurs from toxic metabolites that the cells are unable to clear. Any electrolyte abnormalities should be corrected before re-feeding, which must be introduced very gradually.

Hypercatabolic states

Some patients have greatly increased energy requirements and also an increased need for essential nutrients for extensive tissue repair after injury. However, many of these patients initially are in the 'flow' stage of the general metabolic mobilisation triggered by the cytokines of the systemic inflammatory response syndrome (SIRS). Skeletal muscle is broken down and amino acids are released into the circulation. Additional amino acids also enter the circulation from tissue destroyed by bacterial, chemical or thermal insults.

- The basal metabolic rate (BMR) rises 13 per cent for each 1° Celsius rise in temperature.
- Severe sepsis can double the energy requirements.
- A 40 per cent burn increases the BMR by 60 per cent.

Attempts to match the energy requirements from external sources during this early catabolic phase are misguided, as it will not stop the mobilisation of structural protein. The mobilisation is usually in excess of that needed for the repair and replacement that the body can undertake at this stage. As there is therefore already a major source of fuel, feeding with excessive additional intravenous glucose results only in hyperglycaemia. Excessive administration of amino acids is also counterproductive in this early phase, as they place additional strain on the already stressed metabolic pathways and merely require to be broken down and the nitrogen excreted. A positive nitrogen balance cannot be achieved until the anabolic recovery phase has been reached. Monitoring of nitrogen losses in the urine may give an indication of the severity of the insult suffered or the time it will take for full convalescence, but does not provide any guide as to the requirements for nitrogen in the ensuing 24–48 hours.

In patients in whom a high-calorie, high-protein regimen is desirable, simply increasing the intravenous feeding regimen to increase calories and nutrients has problems. Fluid overload and nutrient overload can occur. Lipid is poorly cleared from the circulation, and poorly metabolised, in severe infections. Glucose oxidation and storage are also impaired by sepsis and other causes of SIRS, although utilisation can be restored to near-normal by insulin administration on a sliding scale to keep blood glucose concentrations within the normal range. There is, however, a metabolic ceiling for glucose oxidation, even in a patient who is not metabolically compromised.

The nitrogen content in a regimen can be increased, and this is important in patients who have large external losses from burns or fistulae. Increased urinary nitrogen loss, as explained above, is seldom an indication for increasing parenteral delivery of nitrogen. Low serum albumin levels are more often an indication of a severe underlying illness or ongoing sepsis, and are not specific or sensitive markers of severe malnutrition.

Amino acids should not be given without a simultaneous energy supply.

- 100–200 carbohydrate kcal/g of nitrogen is recommended.

Long-term parenteral feeding

Long-term parenteral feeding for established intestinal failure was discussed in Chapter 12. The requirements of micronutrients, trace elements and vitamins become of increasing importance, and these patients are normally managed by specialist nutrition teams.

POSTOPERATIVE COMPLICATIONS

Respiratory

Many patients already have some degree of respiratory compromise preoperatively, but respiratory function is further challenged by a general anaesthetic and surgery. In general, management consists of correction of mechanical problems, adequate pain relief, intensive physiotherapy, antibiotics and additional oxygen in the inspired air. If despite these measures the P_aO_2 falls below 8 kPa or the P_aCO_2 rises above 7 kPa, then mechanical ventilation should be considered.

Atelectasis

Anaesthetic gases are irritant to the respiratory epithelium, and an increase in bronchial secretions is to be expected. Impaired clearance of secretions is common postoperatively. This not only predisposes the patient to a postoperative respiratory infection, but a plug of mucus can occlude a segmental or even a main bronchus, with atelectatic collapse distally. Coughing may be too painful, and once analgesia is sufficient the patient may be too sedated to wish to cough unless encouraged to do so. Adequate analgesia and regular well-timed chest physiotherapy are therefore essential. An established atelectasis may be treated by dislodgement of the mucus plug by intensive physiotherapy, but bronchoscopy is still sometimes indicated.

Mechanical failure

Mechanical failure of adequate ventilation due to a pleural space filled with air, fluid or blood must be excluded. Tidal volume can also be reduced by a diaphragm that is splinted from raised intra-abdominal pressure and, when gastric dilatation is partly the cause, the situation can be improved by gastric aspiration.

Acute respiratory distress syndrome

Acute respiratory distress syndrome (ARDS) is a diffuse lung injury that occurs 24–72 hours after a range of initial insults (see 'Multi-organ failure', p. 538). General opacification of the lung fields on X-ray is obvious, and the deterioration in respiratory function will often require mechanical ventilation.

Chest infections

Chest infections are a common postoperative complication. The normal commensals of the upper respiratory tract become opportunist pathogens in the increased stagnant secretions of the lower tract. A respiratory tract infection is the most common cause of a pyrexia during the first 3 days after surgery. A pulmonary embolus may also present with dyspnoea and pleuritic chest pain. Differentiation from an infective problem can be difficult when symptoms, signs and X-rays suggest an area of pneumonia.

Cardiovascular

Strokes and myocardial infarctions

Cardiovascular instability, and especially periods of hypotension, are potentially serious in any patient with a stenosis of an artery supplying the myocardium or brain. A perioperative myocardial infarction or cerebrovascular accident can follow an episode of poor perfusion prior to, during or immediately after an operation. Later, the increased coagulability of the blood during the postoperative period predisposes to arterial thrombosis in stenosed arteries, and may again be precipitated by a fall in perfusion. This fall may be associated with a secondary postoperative haemorrhage or with sepsis from an anastomotic leak.[2] The surgeon must be aware of this combination of pathologies, or only the secondary medical problem may be diagnosed and the underlying surgically amenable complication may be missed.

Cardiac failure and inotrope support

Cardiac output and arterial blood pressure may both be depressed in an ill patient. When perfusion of vital organs becomes threatened, inotropic support with adrenaline, noradrenaline or other pressor agent becomes necessary. Such patients require intensive monitoring and frequently also mechanical ventilation, and will have to be transferred to an intensive care unit.

Venous thrombosis and embolus

The prophylaxis of venous thrombosis and pulmonary embolus was discussed in Appendix I, and should continue during the postoperative period until the patient is fully mobile, which in practice is often the time of discharge home. The treatment of an established thrombosis or embolus is anticoagulation.

A clinical diagnosis of deep vein thrombosis is difficult, as signs are unreliable, but various algorithms have been developed that may help in decisions over management. D-dimer levels have negative predictor values and are therefore not helpful during the perioperative period when they are already raised. Doppler ultrasound by an experienced operator is a sensitive investigation, and has now virtually replaced the old 'gold standard' venography.

Accurate clinical diagnosis of pulmonary embolism is also difficult. Treatment must often be started on a presumptive diagnosis, based on clinical suspicion, combined with an analysis of ECG or blood gas results. Subsequently, radiological investigations are important to establish the diagnosis, as if excluded, treatment can be discontinued and several months of further prophylactic anticoagulation therapy will be avoided. Investigations will depend on the facilities available. CT pulmonary angiography is the current gold standard, but ventilation–perfusion (VQ) scanning is still sometimes used.

Initial treatment is with non-fractionated heparin, low-molecular-weight heparin or fondaparinux. Local protocols vary, although classically a loading dose of 10,000 units of non-fractionated heparin (100–200 units/kg) was administered intravenously, followed by heparin infusion of 30,000 units over 24 hours, which was adjusted according to monitoring. Once the diagnosis is confirmed, warfarin anticoagulation is commenced unless there is still a risk of postoperative bleeding. The heparin is stopped once the patient is fully anticoagulated and the warfarin should be continued for 3–6 months.[3] A large pulmonary embolus with right heart failure may require more active treatment with thrombolysis through a pulmonary artery catheter placed by a radiologist. The surgical alternative of a pulmonary embolectomy (see Chapter 8, p. 148) is almost never undertaken. An IVC filter should be considered in patients at high risk of further emboli (i.e. those with a free-floating IVC clot, those with repeat emboli after commencement of heparin and those in whom anticoagulation is contraindicated).

Renal complications

Oliguria

Oliguria, usually defined as a urinary output of less than 20 ml per hour, requires action. Urine retention or a blocked catheter must first be excluded. If the patient is hypotensive or shocked, volume replacement of the extracellular fluid compartment is the first priority. Similarly, if the oliguria is secondary to poor perfusion due to cardiac failure, this should be treated. If neither hypovolaemia nor cardiac failure is the apparent cause, a fluid bolus of 200 ml intravenously should then be given. If this fails to produce a diuresis, a CVP measurement will be helpful. (Further fluid boluses will be detrimental if the CVP is high, and a diuretic challenge contraindicated if the patient is hypovolaemic.)

Established renal failure

Established renal failure requires intensive fluid and electrolyte monitoring. Transfer of the patient to an intensive care or high-dependency environment becomes necessary and the management of their renal failure passes to the intensivists. Fluid overload, hyperkalaemia and acidosis are the main threats. The risk of upper gastrointestinal bleeding is increased and prophylactic H_2 antagonists or sucralfate should be given. Nephrotoxic drugs must be avoided. Hyperkalaemia of over 6.5 mmol/l must be reduced urgently. Conservative measures to reduce potassium levels include correction of the acidosis, glucose and insulin infusions, oral exchange resins, intravenous calcium administration and high-dose frusemide. Renal replacement therapy is indicated for hypervolaemia and for a hyperkalaemia or acidosis that does not respond to conservative treatment (a persistent potassium concentration over 6.5 mmol/l or a pH below 7.2). A variety of renal replacement techniques are available, but the most commonly used in the acute postoperative patient is continuous venovenous haemofiltration (CVVH) with a pump providing the flow through the system. In the postoperative patient, renal failure is most commonly part of a multi-system failure, and often the patient also requires cardiac inotropes and mechanical ventilatory support.

Intestinal complications

Temporary intestinal failure after abdominal – and particularly gastrointestinal – surgery is common. An ileus usually resolves spontaneously and is seldom life threatening, but more severe manifestations are discussed in Chapter 12. Prolonged intestinal failure results in severe malnutrition. This often goes unrecognised, but is an important cause of increased mortality and morbidity in the surgical patient.

Infective complications

The diagnosis of sepsis during the postoperative period is not always straightforward. A pyrexia and rise in white blood cell (WBC) count or C-reactive protein may also occur as part of a systemic inflammatory reaction to sterile tissue damage. An overwhelming sepsis may result in a fall in WBCs and, particularly in the elderly, the most obvious clinical features may be of cardiovascular decompensation, which is easily misdiagnosed as a primary cardiac complication.

During the first 48 hours after surgery any infection is most likely to be related to the original septic pathology for which surgery was undertaken or to be a respiratory infection. A central line sepsis must also be considered. Dead tissue, whether gut or the soft tissue of an amputation stump, may also present as 'sepsis'. Evidence of sepsis 7–14 days after any intra-abdominal anastomosis must raise the possibility of an anastomotic leak. This possibility must be excluded as urgent re-exploration will often be indicated if a leak is discovered. Intra-abdominal, pelvic and wound abscesses may also present at this time, and respiratory, central line and urinary tract infections are all further possibilities. Antibiotic therapy alone is insufficient if there is necrotic tissue or extensive contamination with infected gastrointestinal contents. Dead tissue must be excised and any pus drained.

Multi-organ failure

Direct tissue injury, whether from a traumatic, surgical, thermal or infective cause, releases into the circulation chemicals from damaged cells, which incite a systemic inflammatory response. The effects include endothelial damage in capillaries throughout the body and subsequent damage in all organs. In addition, these damaged capillaries allow excessive fluid out of the circulation, and even if there is no bleeding wound or weeping burn, there can be a profound hypovolaemia. If aggressive fluid replacement is not initiated early, there is inadequate tissue perfusion and further damage to vital tissue. The mainstay of management is intensive support including inotropes, mechanical ventilation and haemofiltration. The surgeon, however, must be alert to the possibility that there might be an underlying surgically amenable pathology that requires action. An abdominal abscess, dead gut or an intraperitoneal or mediastinal leak from a gastrointestinal anastomosis is the most common scenario.

REHABILITATION

Healing of tissue at the site of operation continues after a patient has been discharged home. Generalised weakness and tiredness following major surgery may take several months to settle, especially if the surgery or the underlying pathology was associated with sepsis or a profound weight loss. Patients require some guidance on return to normal activities, as some unrealistically expect an immediate return to peak physical fitness, while others will delay their full recovery by restricting their activities. Some patients may require specific dietary advice or a course of physiotherapy.

For some patients, a return to their preoperative level of health and lifestyle is not possible. The physical and psychological adjustments to a prosthetic limb, a breast prosthesis or a stoma should not be underestimated. Other patients have to adjust to a shortened life expectancy or a life with major restrictions. When surgeons decide that they do not need to see a patient after discharge from hospital, they must be assured that the patient has sufficient other professional or social support for further recovery from surgery.

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